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1750 MHz TELEMETRY/SENSOR RESULTS FROM HARP FIRINGS AT BARBADOS AND WALLOPS ISLAND, 1965

by

William J. Cruickshank

February 1967

U. S. ARMY MATERIEL COMMAND
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1824

WJCruickshank/ss
Aberdeen Proving Ground, Md.
February 1967

1750 MHz TELEMETRY/SENSOR RESULTS FROM HARP FIRINGS AT BARBADOS AND WALLOPS ISLAND, 1965

ABSTRACT

This report presents the experimental results obtained from seven Martlet II projectiles which were fired from the High Altitude Research Program (HARP) 16-inch gun at Barbados, West Indies, and three projectiles fired from the HARP 7-inch gun at Wallops Island, Virginia, during 1965. These projectiles were instrumented with the BRL 1750 MHz telemetry system and temperature, aspect magnetometer, and Langmuir probe sensors.

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I. INTRODUCTION

The High Altitude Research Program (HARP) was initiated in 1961 as a joint program between the Ballistic Research Laboratories (BRL) and McGill University under contract to the Army. HARP features the use of atmospheric probes launched from 5-inch, 7-inch and 16-inch guns. This report describes the experimental results obtained from seven Martlet II projectiles which were fired from the HARP 16-inch gun at Barbados (Figure 1) and three 7-inch projectiles which were fired from the 7-inch gun (Figure 2) at Wallops Island during the 1965 Ballistic Research Laboratories series. These projectiles were instrumented with the BRL 1750 MHz telemetry system and parachute-temperature, aspect magnetometer and Langmuir probe sensors. The rounds were code named Rufus, Bridgetown, Kendall and Lancaster (parachute-temperature), Brutus, E_1-2446 and E_1-2448 (DC Langmuir probe), and IRE, Janus and E_1-2447 (AC Langmuir probe).

II. TEST OBJECTIVES

The test objectives were as follows:

- To conduct field tests of the BRL 1750 MHz telemetry/sensor system in Martlet IIC and 7-inch projectiles to supplement previous tests of the telemetry system at Wallops Island in the 5-inch gun projectiles
- To conduct the first tests of the BRL 1750 MHz modified GMD angle tracking system on Martlet IIC and 7-inch projectiles
- To make additional payload-temperature measurements to supplement those made previously.
- To conduct the first tests of the parachute temperature sensor system with 1750 MHz telemetry
- To conduct the first flight tests of the DC and AC Langmuir probes on Martlet IIC and 7-inch projectiles

III. DESCRIPTION OF INSTRUMENTATION AND PAYLOADS CARRIED IN PROJECTILES

The 16-inch and 7-inch projectiles were all equipped with the BRL 1750 MHz telemetry systems. Four of the Martlet IIC projectiles fired by the 16-inch gun were equipped with parachute borne temperature sensors and the remaining three projectiles carried Langmuir probes as their

payloads. All three 7-inch projectiles had Langmuir probe payloads. Descriptions of the telemetry and antenna systems, Langmuir probes and payloads carried on specific rounds are discussed below.

A. Telemetry System

The BRL 1750 MHz telemetry system consisted of a frequency modulated 1750 MHz transmitter, one or two sub-carrier oscillators (SCO's), a commutator, a battery pack, an acceleration switch and an antenna. All of the payload telemetry units used one SCO with a center frequency of 10.5 KHz. The rounds carrying an AC Langmuir probe also contained a second SCO with a center frequency of 14.5 KHz.

The telemetry transmitter was the Western Microwave Laboratory "Solistron" which had a power output of approximately 100 milliwatts at 1750 MHz and a modulation sensitivity of approximately 0.25 volt per 100 KHz of RF deviation. The transmitter was 1.125 inches in diameter and 1-inch long.

The sub-carrier oscillators and commutators were developed in-house at BRL. The SCO's had center frequencies of 10.5 and 14.5 KHz with a bandwidth of $\pm$ 7 1/2 percent of center frequency with modulation sensitivities of 5 volts for full bandwidth deviation. The 10.5 KHz SCO was used with the commutator and the 14.5 KHz SCO was used with the AC Langmuir probe.

The commutator had an 8 channel capacity with a frame rate of 5 per second (8x5) providing a sampling rate of 40 samples per second. Two of the channels were paralleled for identification purposes. The units had an input/output signal level capability of approximately 0 to 5 volts. Calibration signals of 5 and 0 volts were used on two channels with the 5 volt source connected to the paralleled identification channels. The remaining 5 channels were used for data transmission.

The telemetry battery pack consisted of 15 type VO-250 nickle-cadmium cells which provided a voltage of 20 volts with a 250 milliampere hour capacity. Acceleration switches fabricated by the Harry Diamond

Laboratories were used as power turn-on devices. The antennas used to transmit information from these payloads were designed at BRL and are described in a later section. A circuit diagram of a typical telemetering system that was flown is shown in Figure 3.

B. Langmiur Probes

The Langmuir probe is a charged particle sensing instrument that is capable of measuring electron density in the 50 to 160 kilometer altitude region of the ionosphere. Both DC and AC Langmuir probes were developed. The AC probe applies a swept voltage, which varies from + 2.4 to -2.4 volts between a metal nose tip collector and the projectile body. The probe is essentially a high gain amplifier with a dynamic range of 5 decades and a logarithmic feedback element. For an electrode area of 100 sq cm a minimum current of 10^{-9} amperes is readable; under these conditions the minimum current corresponds to an electron density of 10 electrons per cubic cm. The DC probe had one decade less sensitivity than the AC probe. The initial prototype model of the Langmuir probe and a miniaturized version, which will be used on all future flights, are shown in Figure 4.

The circuit diagram of the initial prototype model of the AC Langmuir probe is shown in Figure 5. The DC probe circuit is identical to the AC probe circuit without the ramp generator.

C. Martlet 16-Inch Projectile Payloads

Descriptions of the payloads carried by the various rounds are described below.

1. Round IRE. This round was instrumented with the DC Langmuir probe, a telemetry system (one SCO) and an aspect magnetometer. The five commutator channels were used to sample Langmuir probe output, magnetometer output, output of a temperature sensor on the transmitter and two battery voltages. A flush-cavity antenna was mounted in the tail end of the projectile. A block diagram of this system is shown in Figure 6. Figure 7 shows a typical layout of the components within a projectile. Figures 8 and 9 are representative photos of the three Martlet II Langmuir probe payloads.

2. Rounds Brutus and Janus. These rounds were instrumented with the AC Langmuir probe, telemetry unit (two SCO's) and an aspect magnetometer. The five commutator data channels sampled Langmuir probe output, Langmuir probe battery voltage, magnetometer output, transmitter temperature, and two other battery voltages. A block diagram of this system is shown in Figure 10.

3. Rounds Rufus, Bridgetown, Kendall and Lancaster. These rounds carried a parachute, air temperature sensors and a telemetry unit (one SCO). The five commutator channels were used to sample the output from four temperature sensors located at various levels on the parachute shroud lines and an internal payload temperature sensor. A slot-loop (sloop) antenna protruded from the rear of the projectile. Figure 11 shows a block diagram of this payload. A layout of the components is shown in Figure 12. Two views of the payload are shown in Figure 13.

D. Seven-Inch Projectile Payloads

Three Langmuir probe payloads prepared for 7-inch projectiles were similar to the Martlet payloads except that a magnetometer was not flown. Block diagrams of these systems for the DC and AC Langmuir probes are shown in Figures 14 and 15. A local heat sink that was thermally insulated from the projectile body was used around the transmitter. The purpose of this heat sink was to minimize heating and the associated frequency drift due to aerodynamic heating of the projectile body. A mechanical layout of these payloads is shown in Figure 16. A single-turn loop (Halo) antenna was embedded in the fiberglas nose cone. Figure 17 is a pictorial view of the payload before final encapsulation of the wiring.

E. Payload Antennas

The four Martlet IIC projectiles carrying parachute borne temperature sensors had sloop antennas; the three Martlet IIC projectiles equipped with Langmuir probes had cavity antennas. All three 7-inch projectiles had Halo antennas. The three types of antennas are described below.

1. Cavity Antenna. The cavity antenna used with the Martlet IIC Langmuir probe payloads consisted of a shorted section of circular waveguide filled with epoxy-fiberglas and fed with a transverse probe. The fiberglas was used as a loading dielectric to bring the small cavity into resonance at 1750 MHz and it also served as a support for the thin walled aluminum cavity. The cavity feed probe was a metal strip formed on a thin copper-clad fiberglas disk that was sandwiched between the thick disks of fiberglas that filled the cavity. One end of the copper strip was tapered and connected to the inner conductor of the coaxial feed cable from the transmitter. The antenna input impedance was adjusted to 50 ohms by trimming the length, width, and taper angle of the copper strip. A cross-section view of the cavity installed in the Martlet IIC projectile is shown in Figure 17. Figure 18 shows the cavity antenna assembly. The radiation from the cavity consisted of a broad, smooth lobe extending $\pm 70^{\circ}$ from the tail of the projectile (Figure 19).

2. Sloop Antenna. The transmitting antenna used on the Martlet IIC parachute-temperature rounds consisted of a slot-loop configuration called a Sloop. The antenna consisted of an aluminum rod with a slot one-quarter wavelength long that was terminated in a small cylindrical cavity (Figures 12 and 13). The antenna was fed with a half-turn coupling loop that was terminated at the base of the slot. Oversize teflon plugs were forced into the cylindrical cavity to protect and support the coupling loop which was formed by the small inner conductor wire of the coaxial feed cable. The antenna was tuned to resonance at 1750 MHz by trimming the length of the slot. Figure 20 shows dimensional details of the Sloop.

The radiation from the Sloop is partially from the slot and partially from the trapezoidal shaped loop formed by the outer surface of the antenna (Figure 20). Radiation patterns of the Sloop antenna when mounted to protrude from the tail section of the Martlet IIC are shown in Figure 21.

3. Halo Antenna. The telemetry antenna used on the 7-inch projectiles consisted of a single-turn, double-gap loop called a Halo antenna. The loop was formed of 0.08-inch O.D. solid copper-clad coaxial cable wrapped in a groove around the fiberglas nose cone at a point where the circumference was one-wavelength at 1750 MHz (Figure 22). The loop had two gaps, diametrically opposite each other. The coaxial cable from the transmitter was connected at one gap with the shield of the feed cable connected to the outer conductor of the loop at one side of the gap and the inner conductor of feed cable connected to the inner conductor of the loop member at the other side of the gap. The resonant frequency of the Halo was adjusted by trimming the open gap. Adding short tabs of wire reduced the resonant frequency and widening the gap increased the frequency. The entire nose cone was covered with filament-wound glass fiber saturated with epoxy resin.

Electrically the Halo functions as a one-turn helix antenna with broad radiation lobes fore and aft and a null broadside (Figure 23).

IV. DESCRIPTION OF GROUND INSTRUMENTATION

Instrumentation on the ground consisted of the Receiving System, radar and cameras, standard Fastax and smear cameras were used on all firings at each location.

A. Receiving System

The BRL designed receiving and recording system is used at Barbados and Wallops Island for telemetry reception. The GMD tracking system provides automatic pointing of the antenna toward the telemetry payload and gives azimuth and elevation angle data at one second intervals. The receiving van provides reception, demodulation and real time chart records of the telemetry signals and back-up tape records of all data. Real time received signal levels are also recorded on a paper chart. The tracking antenna and van are shown in Figures 24 and 25.

B. Radars

The MPS-19 and MPS-33 radars were used for skin tracking all HARP projectiles at Barbados. The FPS-16, MPS-19, and SCR-584 Mod II radars were used for skin tracking of HARP projectiles fired at Wallops Island, Virginia.

V. DISCUSSION OF FIRING TEST RESULTS

A. Sixteen-Inch Payloads

1. Parachute-Temperature Rounds.

Rufus - The payload did not eject. Radio frequency transmission was good from 10 to 233 seconds except for two periods of no signal (Figure 37). The SCO did not function, therefore, no temperature data were obtained. GMD angle tracking was good.

Bridgetown - The payload ejected but the parachute was not deployed. Reduced radio frequency power occurred during the flight with two periods of no signal (Figure 41). The SCO did not function. No temperature data were obtained but GMD tracking was good.

Kendall - The payload was ejected but the parachute was not deployed. Radio frequency transmission was not obtained until 219 seconds but continued thereafter until impact. The SCO and commutator functioned but no air temperature data were obtained due to severed parachute shroud lines. Temperature data on the transmitter package were obtained during the last half of the flight trajectory.

Lancaster - The payload was ejected but the parachute was not deployed. Radio frequency transmission was excellent and continuous from launch to impact (Figure 42). The SCO did not function therefore no temperature data were obtained.

The difficulty experienced with payload ejection and parachute deployment is suspected to be due to mechanical failure of the payload structure which is subjected to high impulse loading by the explosive charge used for ejection. The payloads were held in place by metal shear pins at the tail end of the projectile. It is possible that while shearing the pins the fiberglas cylinder surrounding the electronics crushed or buckled; thus the cylinder jammed in the projectile and also caused damage to the SCO's which were located at the top end of the

cylinder. The parachute failures could have been caused by fouling of the shroud lines or tearing of the parachute due to a slightly unsymmetrical separation of the split-metal container as it was forced out of the projectile.

2. DC Langmuir Probe Round

Brutus - Good radio frequency transmission was obtained throughout the flight except for two short periods of no transmission (Figure 39), probably due to antenna pattern nulls. All airborne components functioned well and good Langmuir probe and temperature data were obtained. No GMD tracking was obtained because of a circuit breaker failure on the receiving antenna mount.

3. AC Langmuir Probe Rounds

IRE - Strong, continuous radio frequency transmission was received up to 76 seconds and then long periods of no signal occurred interrupted by short periods of transmission (Figure 38); this behavior was possibly due to the changing attitude of the projectile. The 14.5 KHz SCO and the Langmuir probe failed; therefore, no data were obtained. The vehicle suffered a damaged fin and flew 100° to the right of a normal course. Tracking by GMD was fair, but it was the only instrument that tracked the vehicle. Plausible reasons for the failure of the SCO and Langmuir probe are not known. Units identical to these had successfully withstood other flight tests and repeated high-g lead tests.

Janus - Excellent radio frequency transmission was obtained from launch to 208 seconds (Figure 40). All airborne components except the Langmuir probe functioned well. Temperature data were obtained and the GMD track was good.

B. Seven-Inch Payloads

1. DC Langmuir Probe Rounds.

E_1-2446 - Good Radio frequency transmission was obtained throughout the flight except for a signal dropout period from 140 to 210 seconds (Figure 43) possibly associated with projectile attitude changes. All of the electronics except the Langmuir probe and SCO functioned normally. The Langmuir probe did not function at all due to

a mercury bias battery failure, and the SCO frequency had a high drift rate. Temperature data at the transmitter were obtained and GMD tracking was good.

E_1-2448 - Radio frequency transmission occurred during the period of 44-110 seconds and was extremely weak (Figure 45) most probably due to antenna connection failure. Due to the weak signals, no data or GMD tracking were obtained.

2. AC Langmuir Probe Round.

E_1-2447 - Radio frequency transmission was fair from launch to 170 seconds except for one no-signal period of 30 seconds (Figure 44).

C. Langmuir Probe Results

Good DC Langmuir probe data were received from Round Brutus (Figure 26). The electron densities agree very well with those expected in the D-region of the ionosphere between 65 and 110 kilometers. A collector current of 1.7×10^{-6} amperes was observed at launch which decreased to 4.0×10^{-8} amperes during the first 50 seconds of flight. This phenomenon was probably due to shunting contaminants on the surface of the nose tip collector which evaporated or burned off during flight. The same effect has been observed on rocket flights. The Langmuir probe data obtained on the other flights could not be interpreted accurately because of calibration difficulties.

D. Temperature Sensor Results

On-board temperature data were obtained during the rounds Brutus, Janus, Kendall and E_1-2446 (Figures 27, 28 and 29). The sensors on rounds Brutus and Janus were located at the rear of the projectiles, in the vicinity of the fins. These data indicated that the transmitter temperatures had reached 67 to 69° C when the transmission ceased. Apparently the increased current drawn by the heated transistors caused the transmitters to fail. The temperature sensor on round Kendall was also located on the transmitter. This payload was ejected from the rear of the parachute at approximately 100 seconds. Since transmission from the payload was not received until 219 seconds, temperature data were

provided for only a portion of the flight (Figure 28). Apparently the transmitter, which was in a heat sink, received a quantity of heat due to aerodynamic heating but was then equalized (at 250 seconds) and cooled by the ambient air temperature. The sensors on round E_1-2446 were located at the transmitter and on the transmitter heat sink. The curves in Figure 29 show the results of this shot and the differences in temperature between the transmitter and heat sink.

E. Magnetometer Results

Rounds IRE, Brutus, and Janus were instrumented with aspect magnetometers, but the instruments failed to function on all three flights.

F. GMD Tracking

Angle tracking data were obtained with the modified GMD tracking unit on seven of the ten projectiles fired. On two flights the RF signals were either too weak or erratic and the loss of track on the third flight was due to a circuit breaker failure on the tracking mount. On one round, IRE, which veered off course more than 100° after launch because of a damaged fin, the modified GMD tracking unit was the only tracker which succeeded in acquiring and tracking the projectile. The tracking data are shown in Figures 30 through 36.

G. Received Signal Strength

Received signal strength data were recorded on each flight as a function of time. These data were then used in conjunction with slant range, obtained from the radar data, to plot the charts of received signal level versus slant range as shown in Figures 37 through 45. The calculated received signal levels for IRE, Brutus, and Janus were based on 200 Mw of power and 0 db of gain for the cavity antenna that was used on these flights. The data from the plots show values 3 to 12 db above theoretical values; this is attributed to the gain of the cavity antenna.

The sloop antenna was used on shots Rufus, Bridgetown, Lancaster, and Kendall. The magnitude and rate of decrease of signal with distance from Rufus was very close to theoretical values (within 2 db),

substantiating the preflight antenna measurements which indicated that the sloop had a high efficiency and a broad pattern. The signal from Lancaster was weak prior to ejection of the payload, but it increased to the theoretical value after ejection; this behavior indicates a mismatch of the antenna due to the presence of the projectile body.

The Halo antenna was used on the 7-inch projectiles E_1-2446, E_1-2447, E_1-2448. The received signals were from 5 to 15 db below theoretical on E_1-2446 and 0 to 10 db down on E_1-2447 except for apparent pattern nulls of 20 to 30 db, which from previous pattern data could be due to near broadside aspects, (i.e., extreme projectile coneing).

H. Radar Data

Figures 46 through 52 show plots of radar trajectories of the vehicles that were tracked. The plots on rounds Brutus, Bridgetown, Kendall, and Lancaster were obtained from the MPS-19 radar on Barbados. The plots on E_1-2446, E_1-2447 and E_1-2448 were obtained from the FPS-16 radar on Wallops Island.

VI. SUMMARY AND PLANS

A summary of the pertinent data and details obtained on the ten rounds fired during 1965 are listed in Table I.

An effort will be made to reduce temperature effects on the 1750 MHz transmitter. A supplement to the contract with Western Microwave Laboratories has been processed for the redesign of the Solistron transmitter to employ temperature compensation and improved efficiency. Thermal insulation and a local heat sink, isolated from the projectile body, will be employed on future flights.

We shall attempt to minimize telemetry component failures by improving the mechanical design, wiring methods, and encapsulation techniques. It is expected that more reliable, lighter, and less costly telemetry circuits will eventually be available as a result of use of hybrid integrated circuits.

ACKNOWLEDGEMENTS

The 1750 MHz telemetry payloads described are a result of the efforts of the Electronic Methods Branch of the Ballistic Measurements Laboratory of BRL. Mr. James Evans was responsible for the projectile payload electronics and integration. Messrs Victor Richard and Harvey La Fon developed the projectile antennas and conducted many radiation tests of various antenna configurations, and Mr. James Pilcher was responsible for the mechanical design of the projectile payloads. In addition, members of the Free Flight Aerodynamic Branch of the Exterior Ballistic Laboratory of BRL provided technical assistance and conducted the high g lead impact tests and the projectile firings at Wallops Island, Virginia. Members of the Space Research Institute, McGill University, conducted the projectile firings at Barbados, West Indies.

TABLE I - 1750 MHz TELEMETRY, 1965

	Test No.	1	2	3	4	5	6	7	8	9	10
	Round No.	Rufus	IRE	Brutus	Janus	Bridgetown	Kendall	Lancaster	E_1-2446	E_1-2447	E_1-2448
A.	Firing Site	B'dos	B'dos	B'dos	B'dos	B'dos	B'dos	B'dos	Wallops	Wallops	Wallops
B.	Date	2 Jun 65	3 Jun 65	5 Jun 65	5 Jun 65	17 Nov 65	19 Nov 65	20 Nov 65	15 Dec 65	15 Dec 65	15 Dec 65
C.	Gun Size	16"	16"	16"	16"	16"	16"	16"	7"	7"	7"
D.	Launch Velocity	4870	[illegible]947	5950	5980	4817	4658		5220	5270	5270
E.	Launch "g"	-	-	-	-	-	-	-	53,500	54,800	55,300
F.	Apogee (ft.)	260K	300K+	390K	386K	278K	240K	195K	265K	260K	242K
G.	Experiment	Para-Temp	Lang. Pr.	Lang. Pr.	Lang. Pr.	Para-Temp	Para-Temp	Para-Temp	Lang. Pr.	Lang. Pr.	Lang. Pr.
H.	Antenna Type	Sloop	Cavity	Cavity	Cavity	Sloop	Sloop	Sloop	Halo	Halo	Halo
I.	Payload Flight Time	233	233	240	240	529	480	446	262	258	263
J.	Telemetry Data										
	1. RF Transmit Time	6-99 131-196 212-233	0-75 92-99 109-113 225-233	0-115 176-197 201-240	0-208	3-37 99-106 130-529	219-480	0-446	0-140 208-262	0-100 130-170	44-110
	2. RF Freq. Shift	Unk	14 MHz	44 MHz	32 MHz	-	-	-	-	-	-
	3. 10.5 SCo Funct	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes
	4. 14.5 SCO Funct	-	No	-	Yes	-	-	-	-	Yes	-
	5. Comm. Funct	Unk	Yes	Yes	Yes	Unk	Yes	Unk	Yes	No	Yes
	6. Payload Eject.	No	-	-	-	Yes	Yes	Yes	-	-	-
	7. Eject Time	-	-	-	-	Unk	110	89	-	-	-
	8. Para Deployed	No	-	-	-	No	No	No	-	-	-
K.	Exper. Data	None	None	Lang. Pr. Temp	Temp.	None	None	None	Temp.	None	None
L.	GMD Tracking	Good	Fair	None	Good	Good	Good	Good	Good	None	None

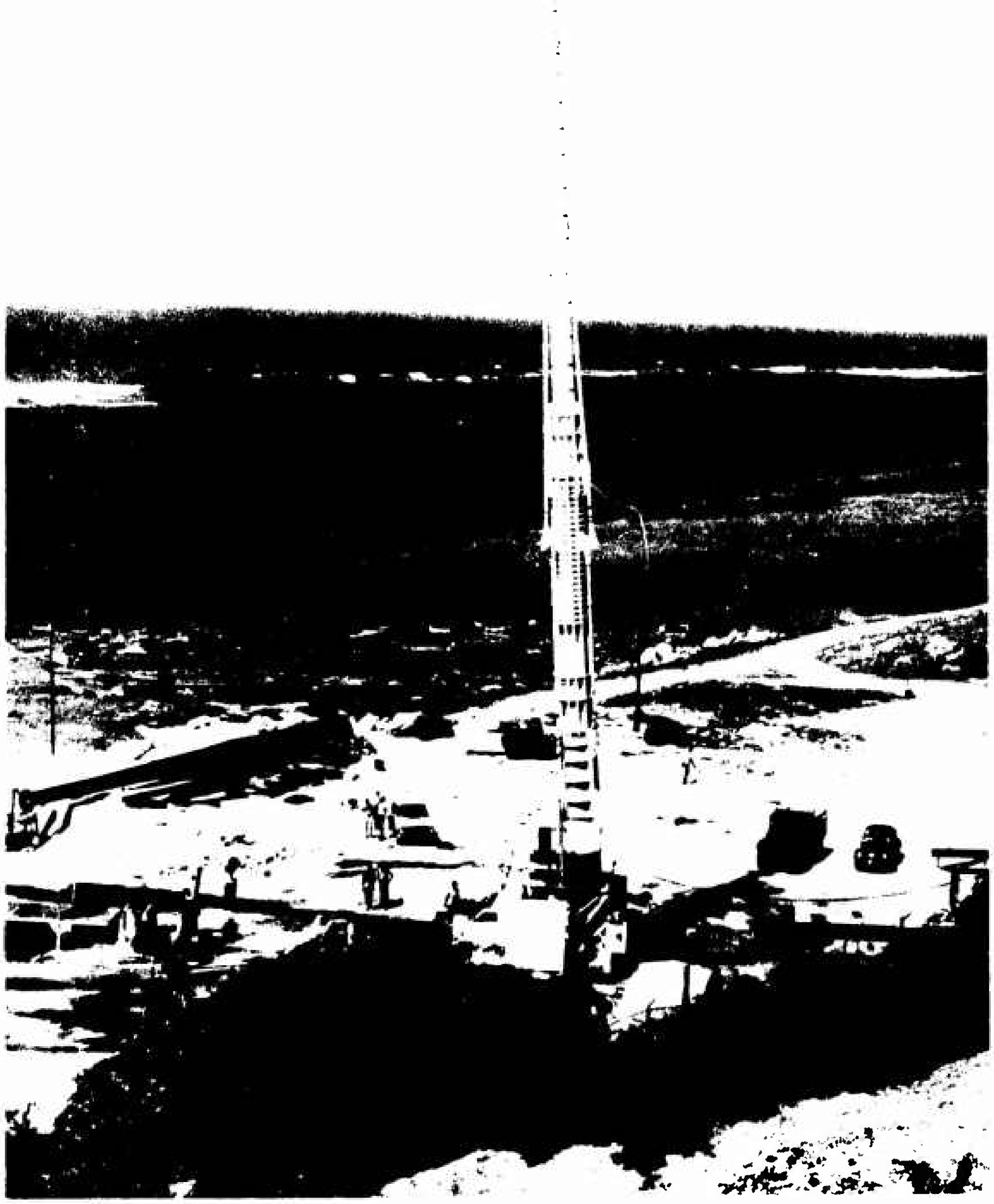


Figure 1. Sixteen-inch gun at Barbados

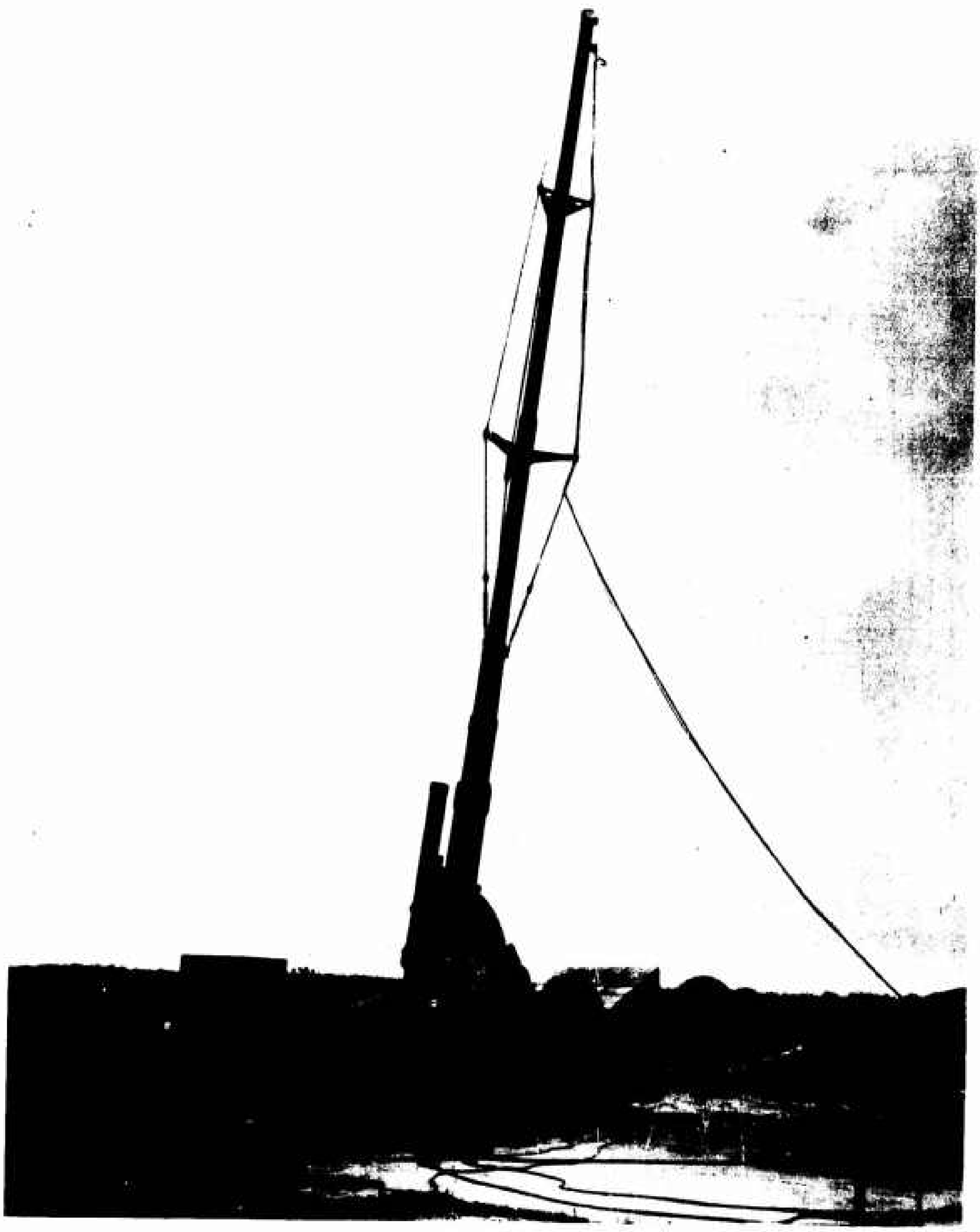


Figure 2. Seven-inch gun at Wallops Island

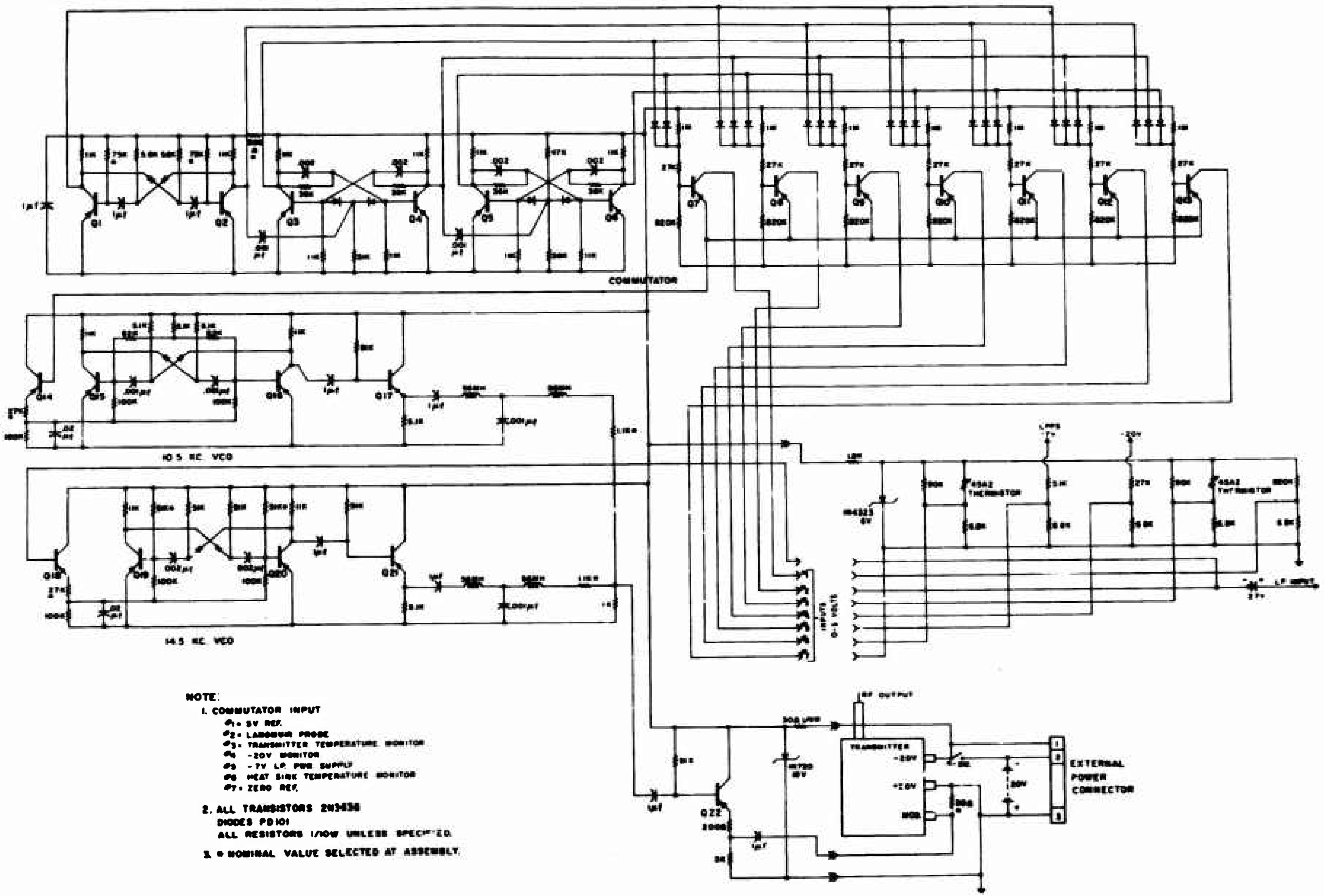


Figure 3. Diagram of 7-inch gun probe telemetry circuit

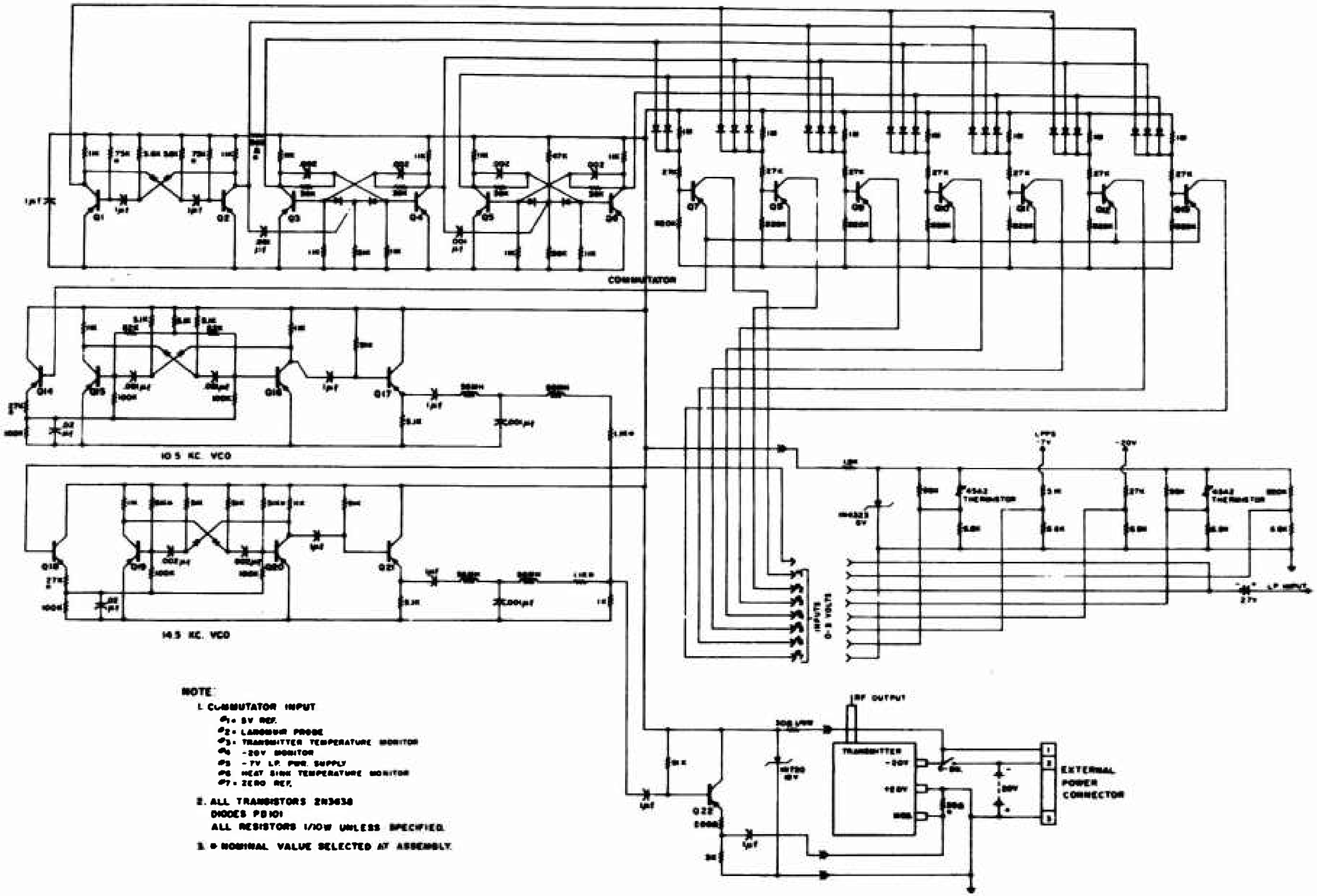


Figure 3. Diagram of 7-inch gun probe telemetry circuit

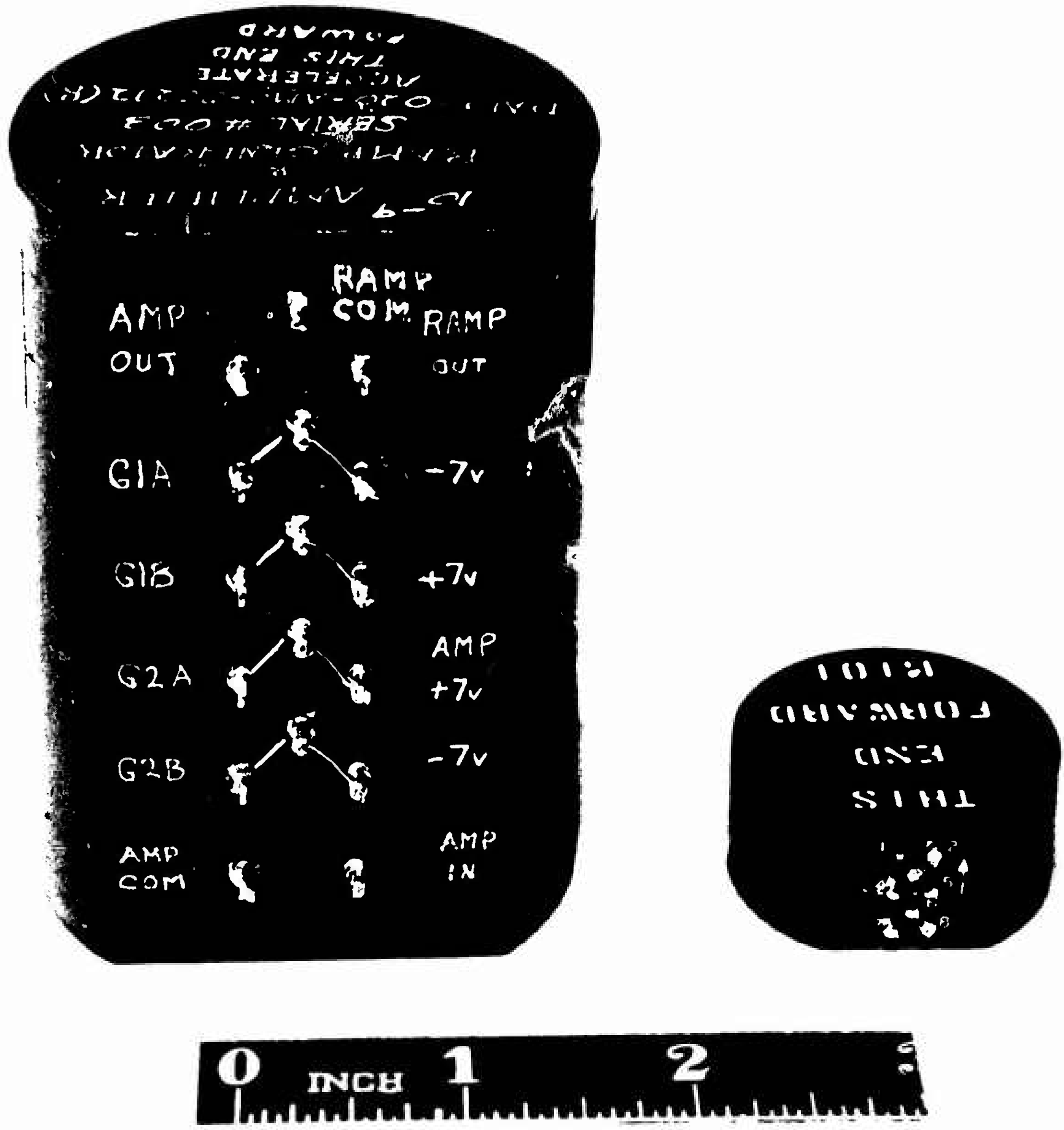


Figure 4. Langmuir probe models

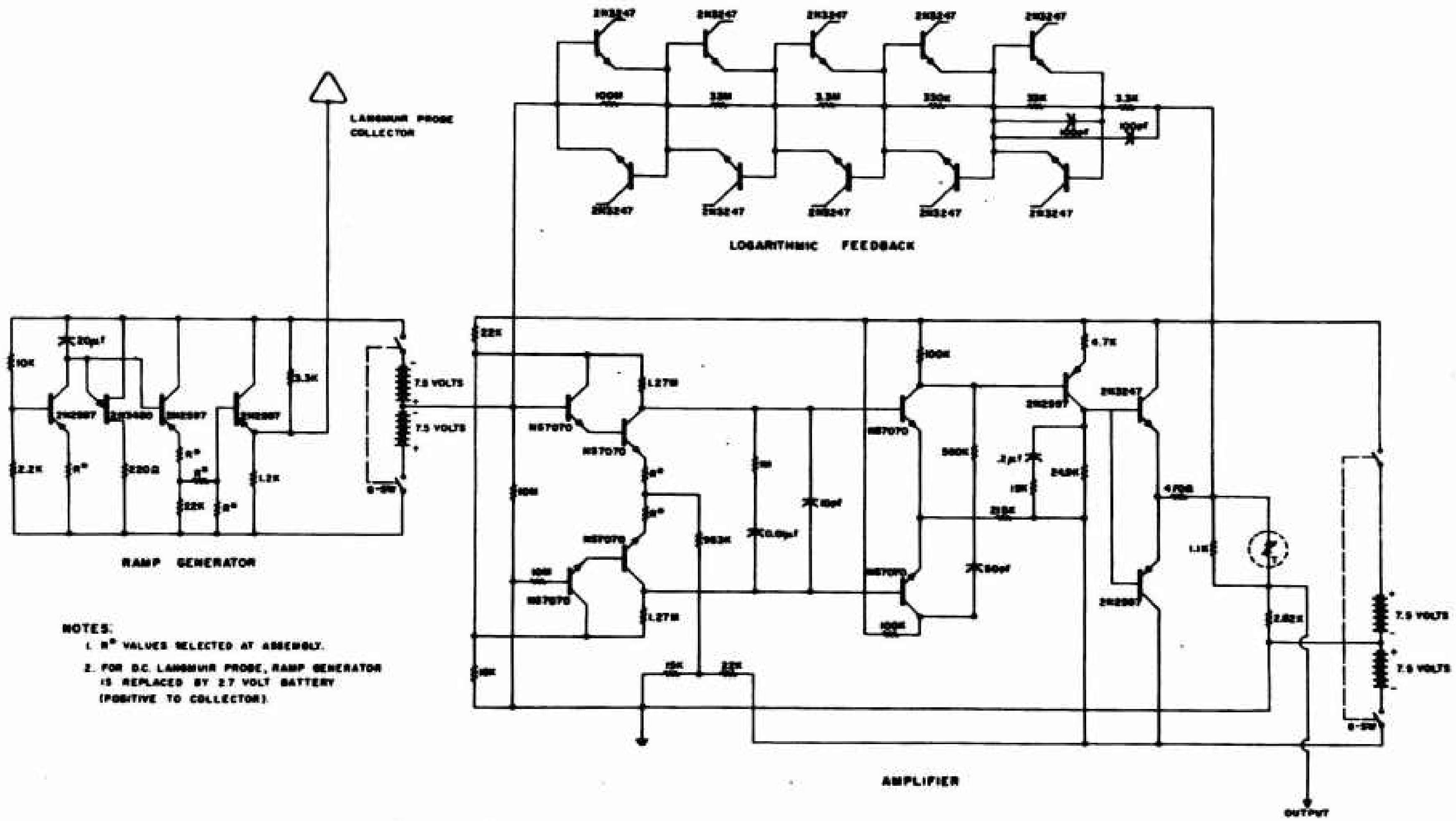


Figure 5. Circuit diagram of AC Langmuir probe

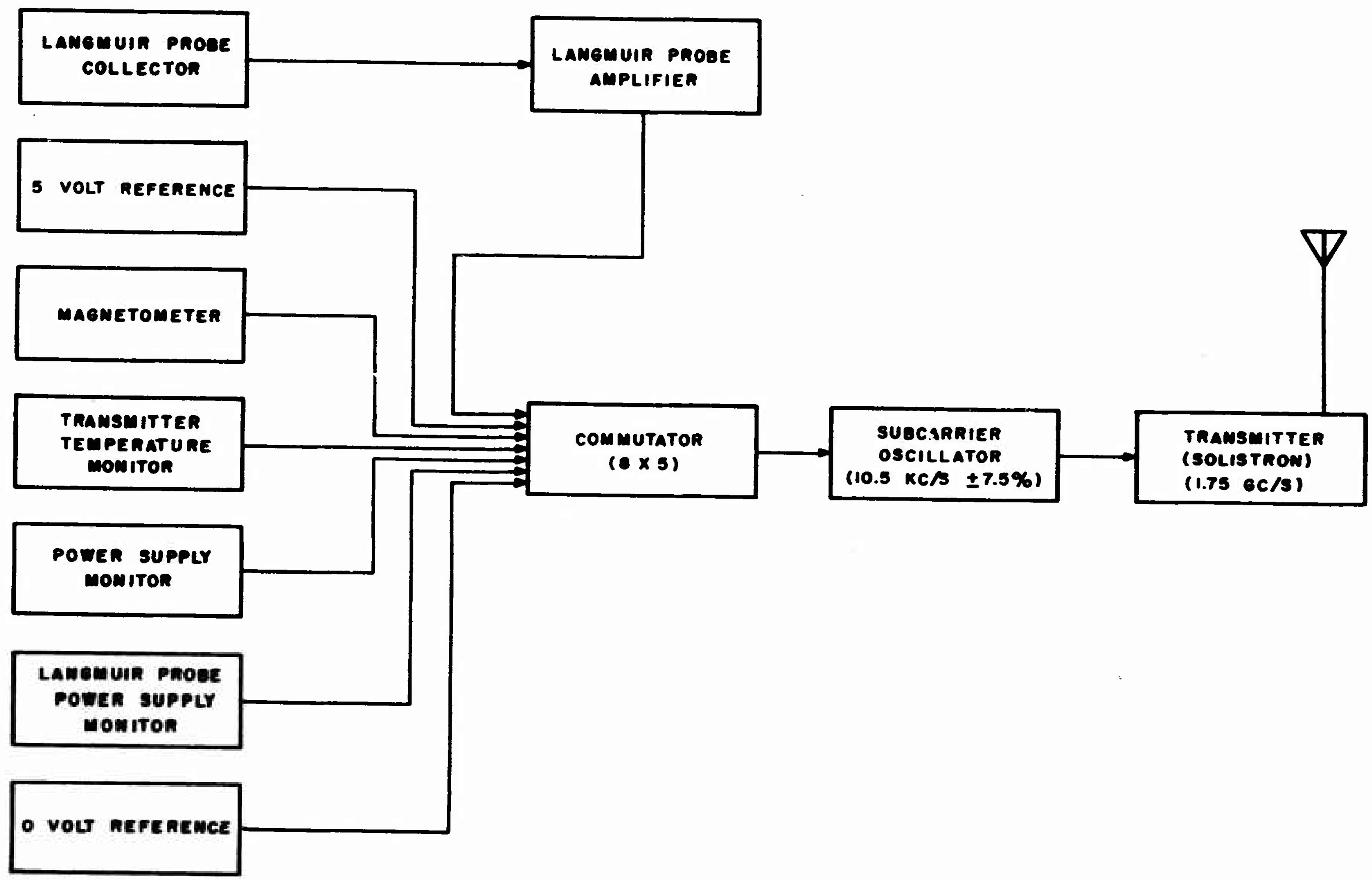


Figure 6. Block diagram of Martlet DC Langmuir probe

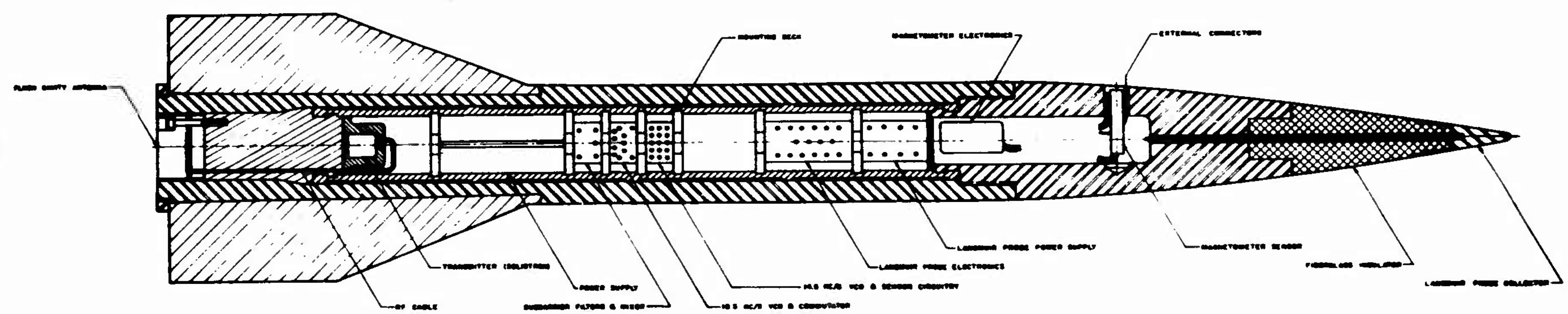


Figure 7. Martlet IIC projectile with Langmuir probe payload

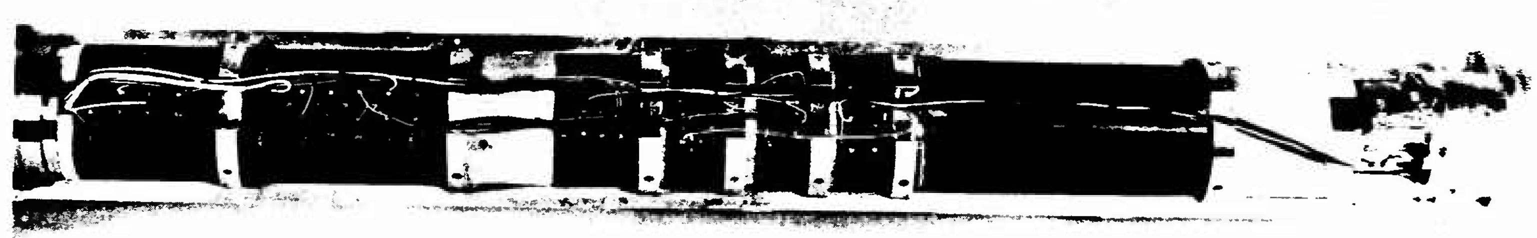


Figure 8. View showing Martlet Langmuir probe components

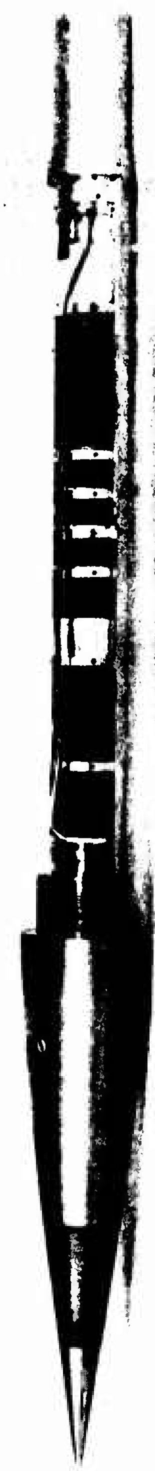


Figure 9. Martlet Langmuir probe payload

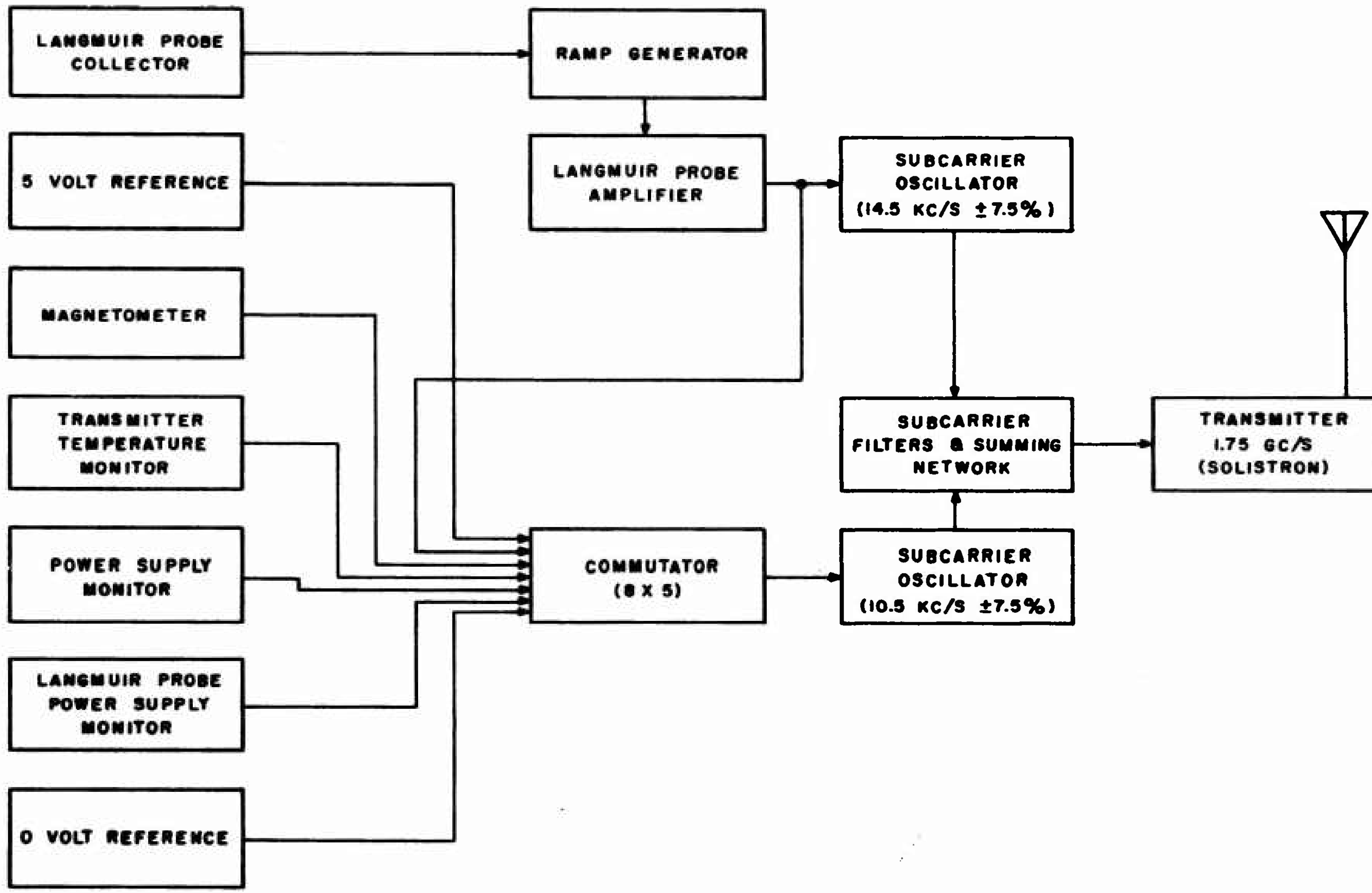


Figure 10. Block diagram of Martlet AC Langmuir probe

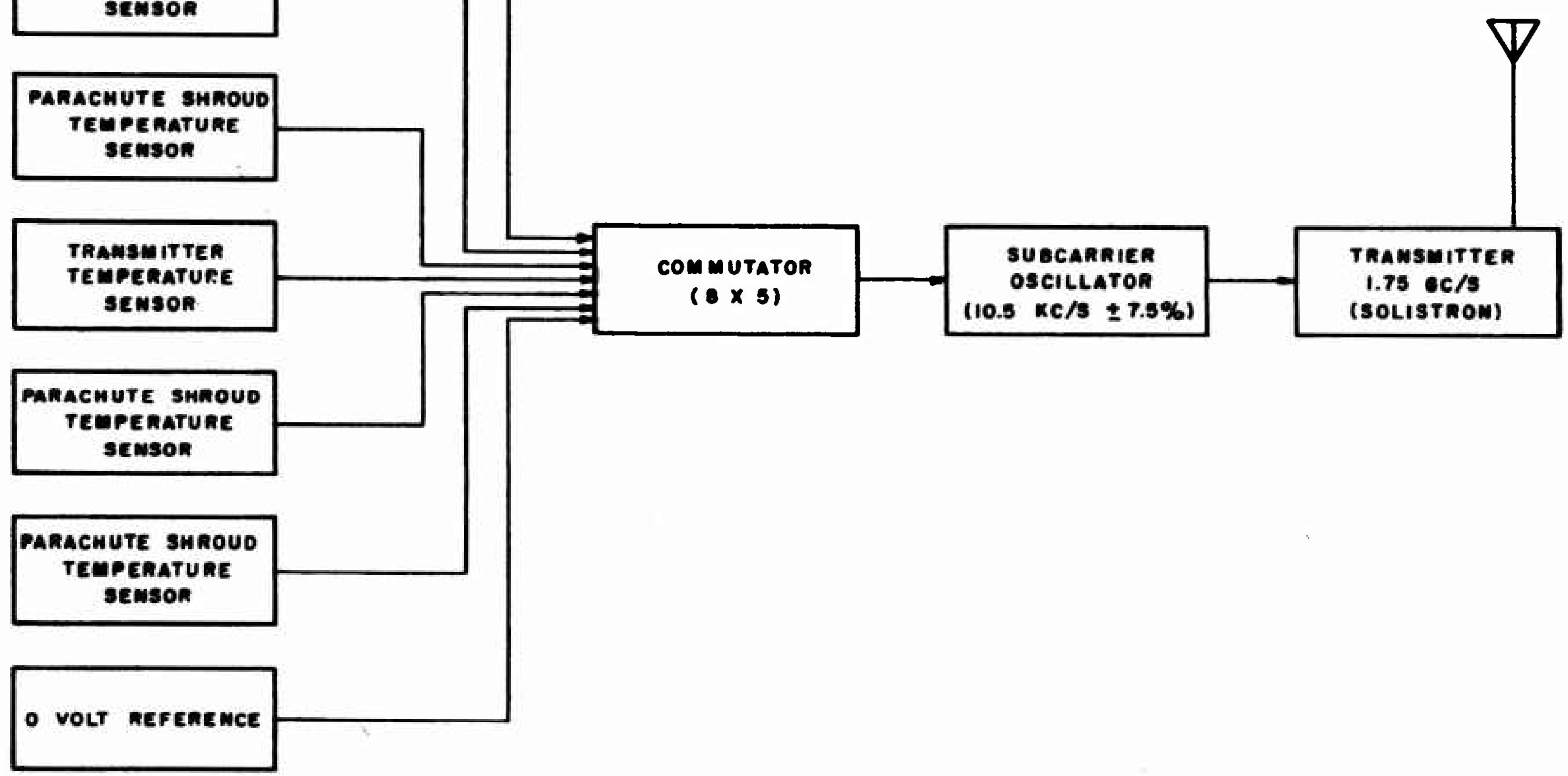


Figure 11. Block diagram of Martlet para-eject payload

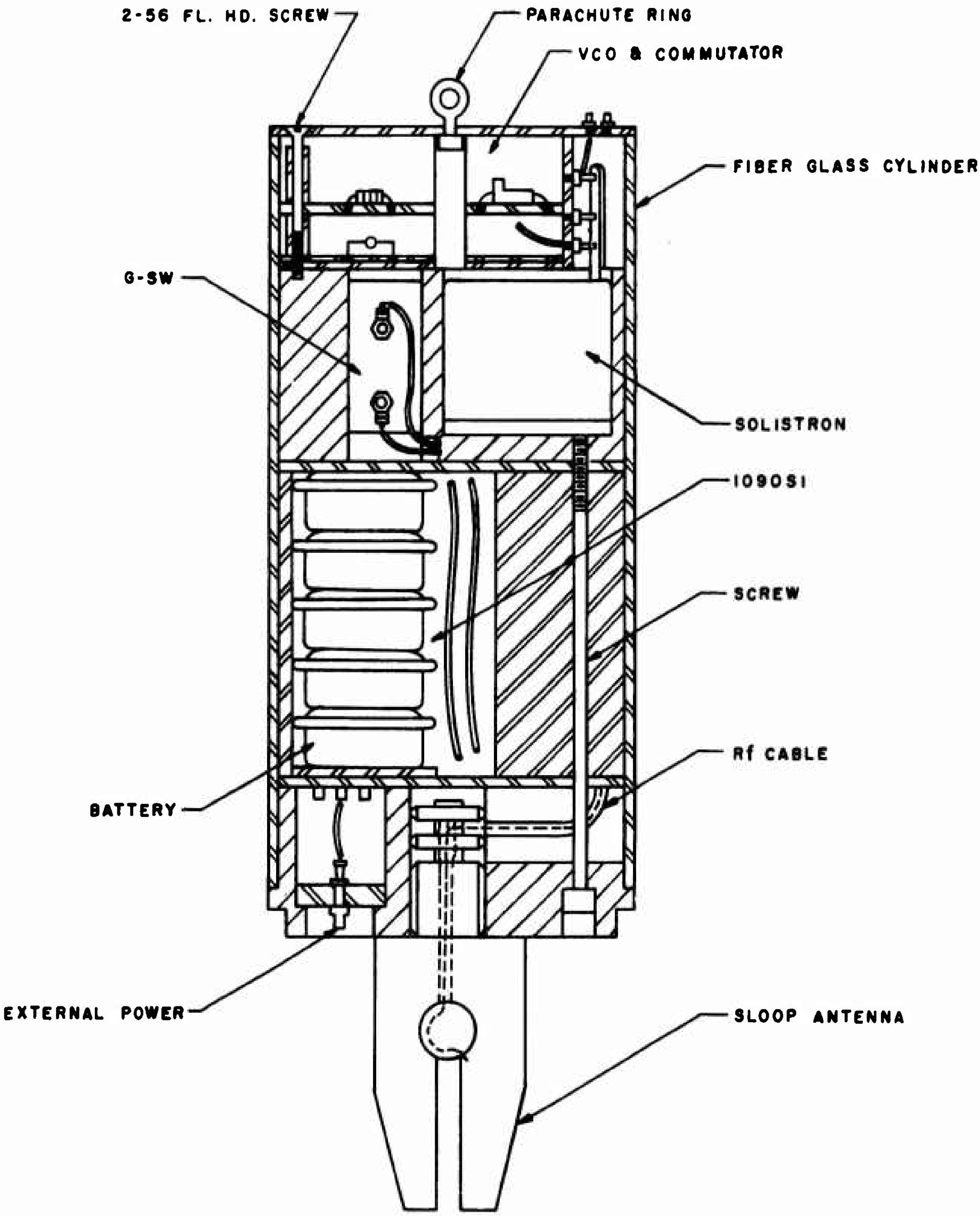


Figure 12. Layout of Martlet para-eject components

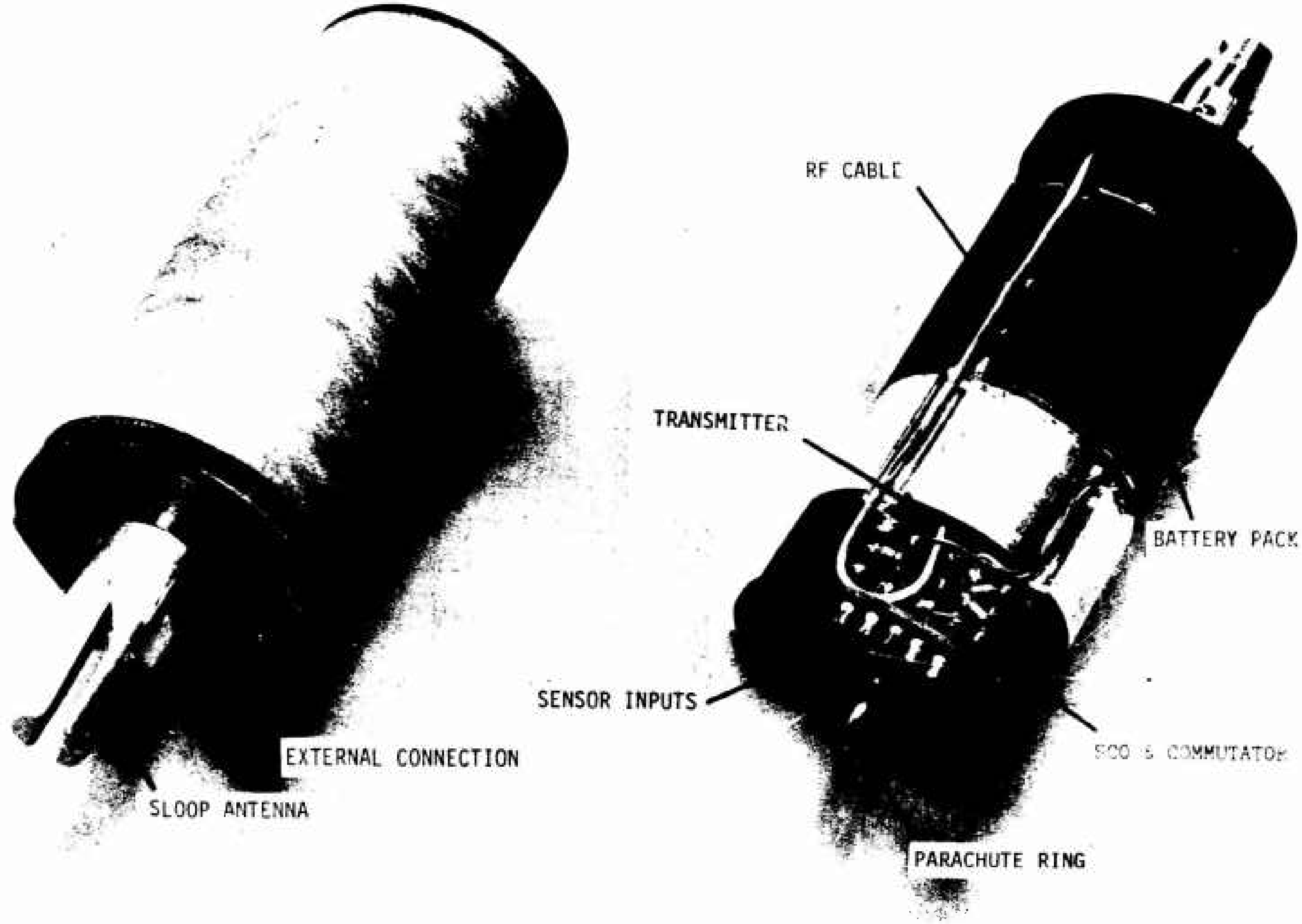


Figure 13. Views of Martlet para-eject payload

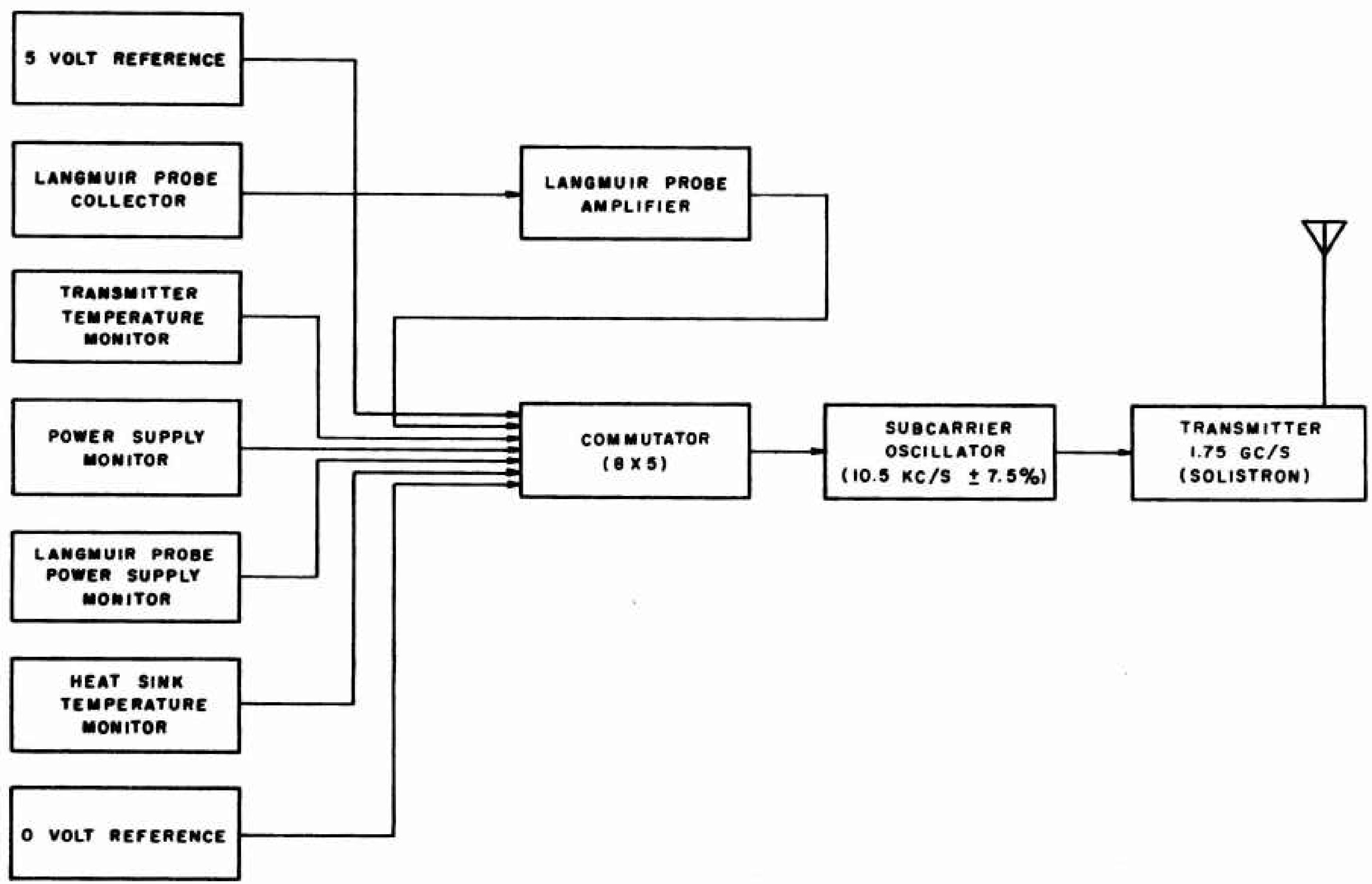


Figure 14. Block diagram of 7-inch D.C. Langmuir probe

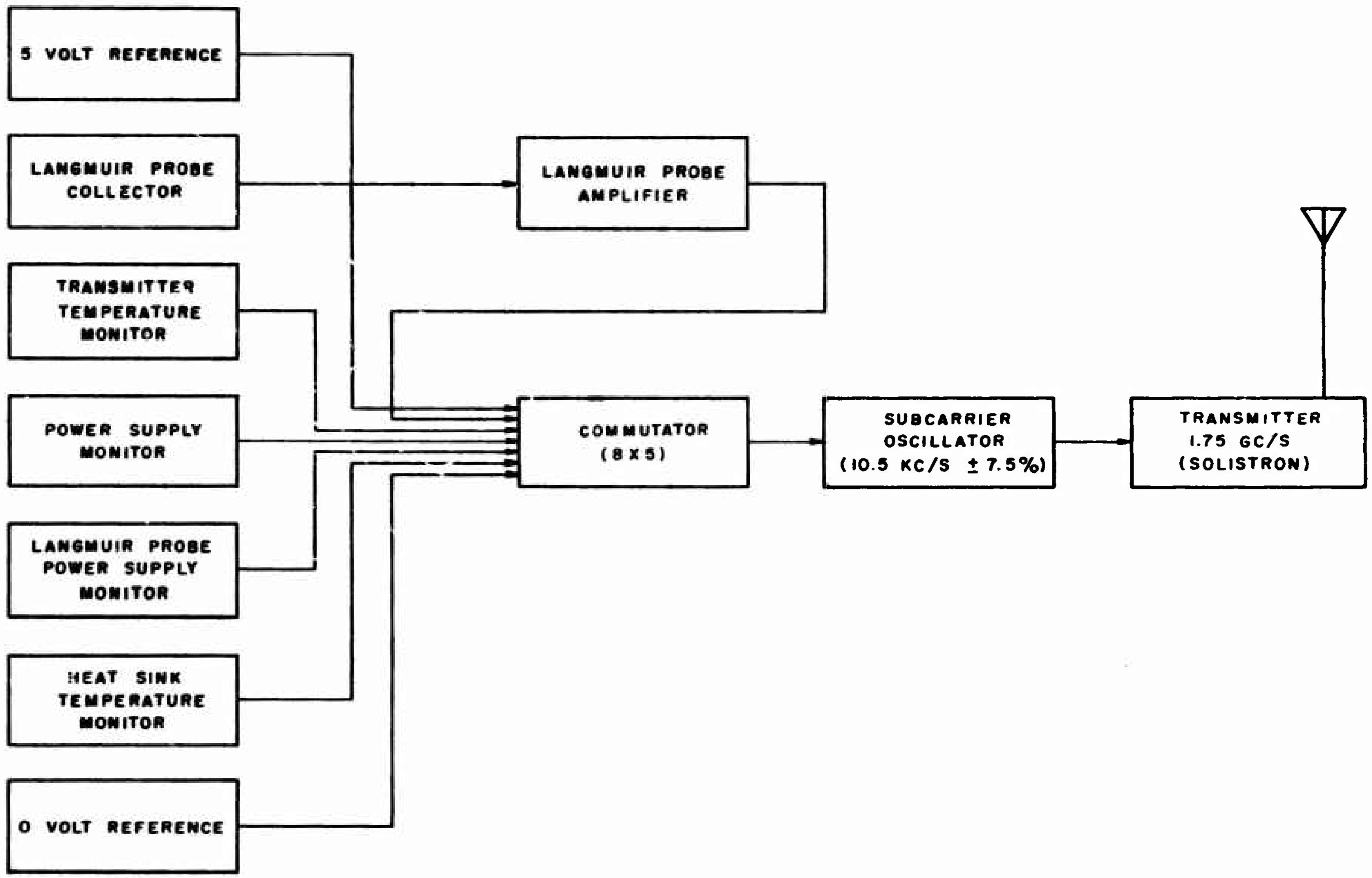


Figure 14. Block diagram of 7-inch D.C. Langmuir probe

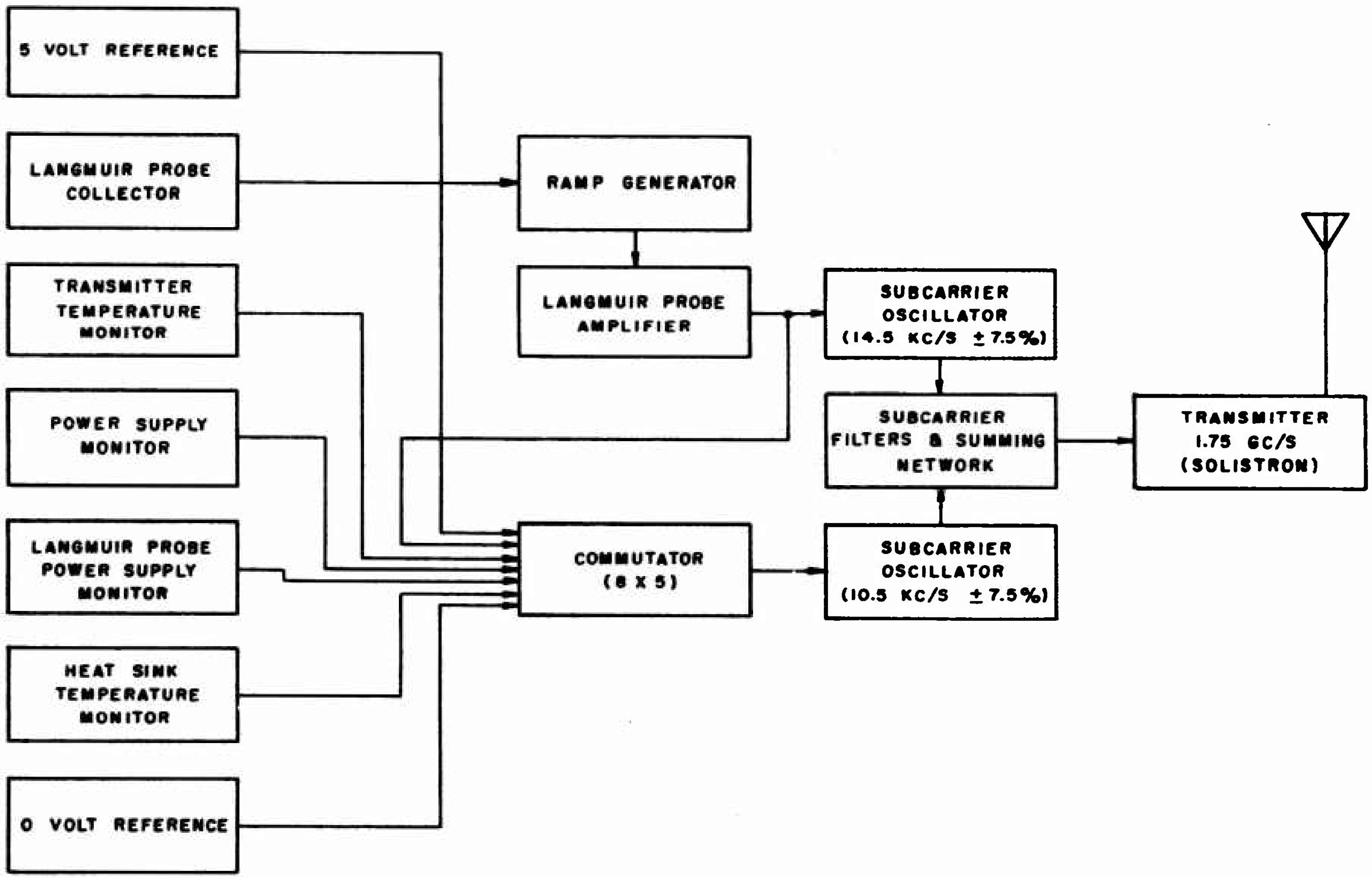


Figure 15. Block diagram of 7-inch A.C. Langmuir probe

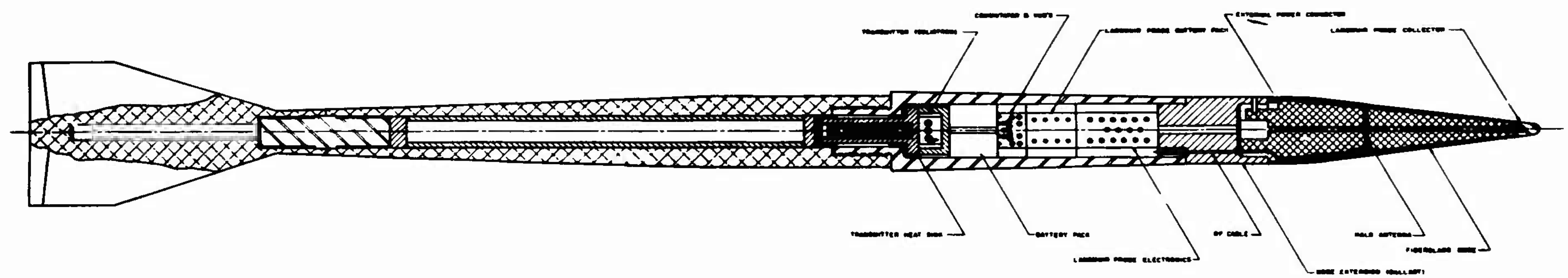


Figure 16. Mechanical layout 7-inch Langmuir probe payload

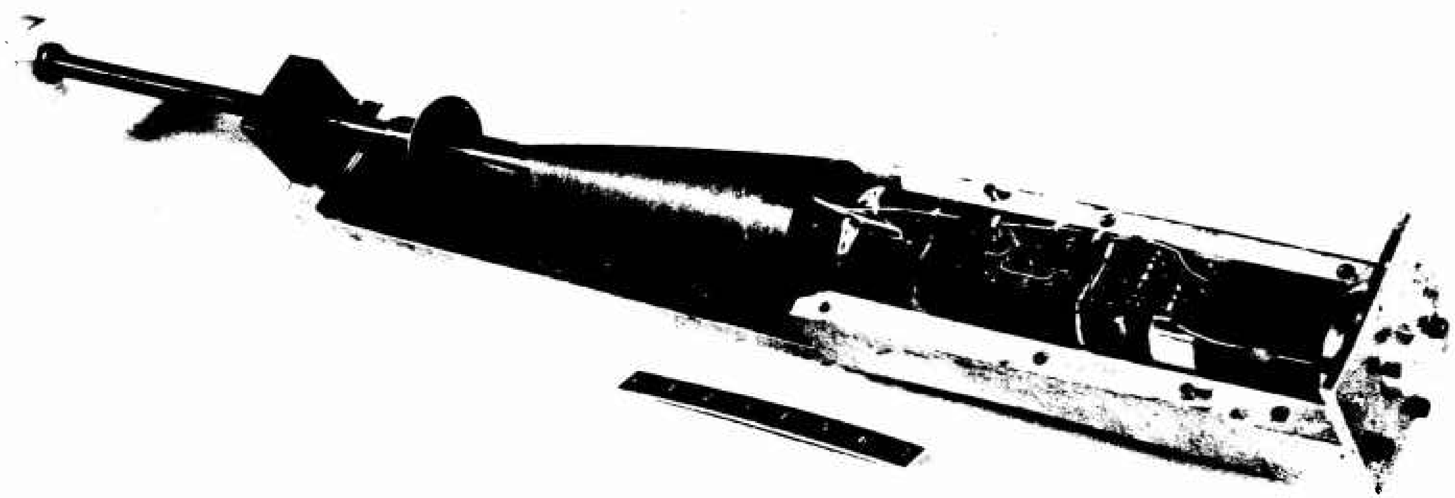


Figure 17. Component wiring in 7-inch Langmuir probe payload

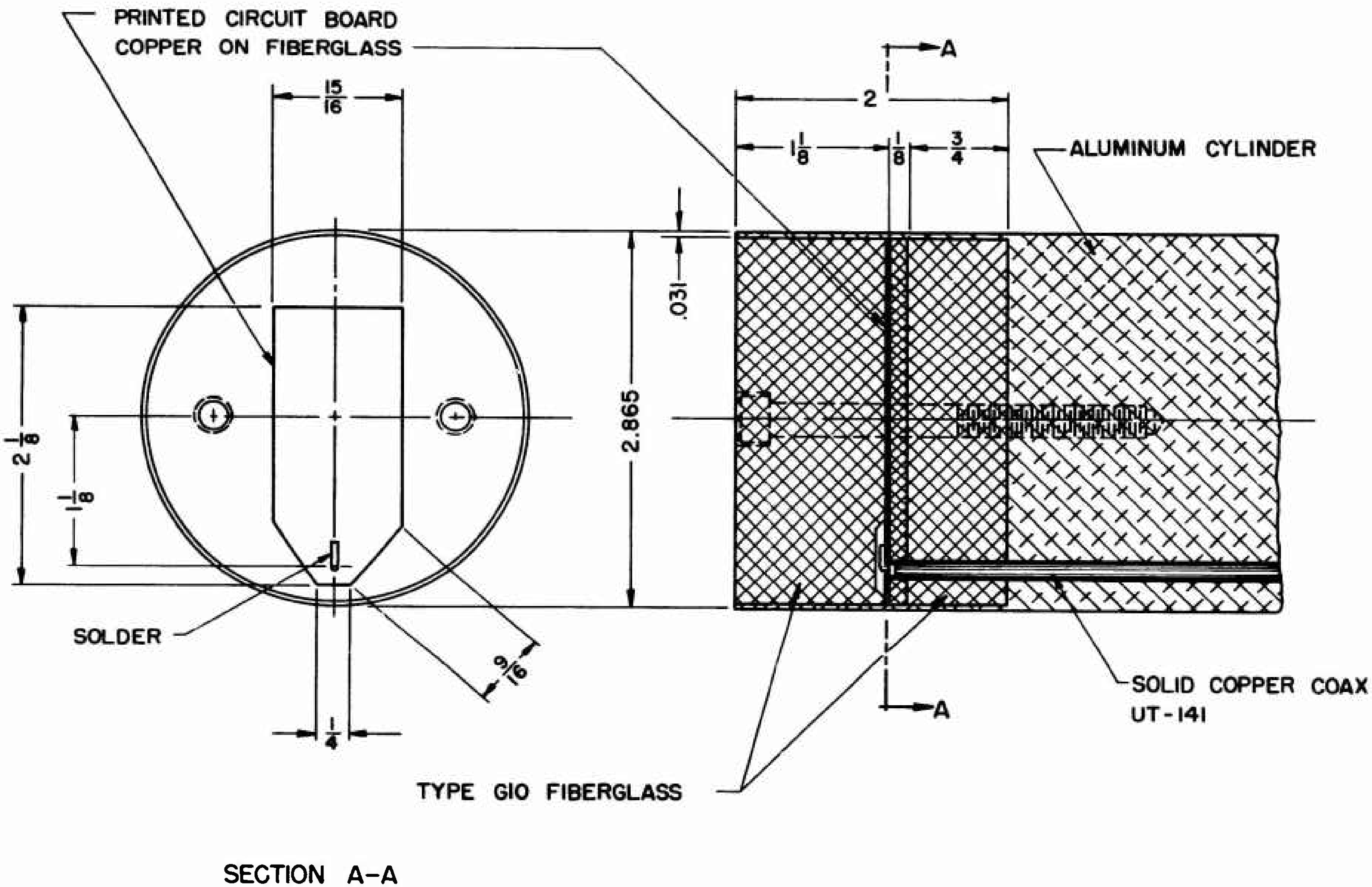


Figure 18. 1750 MHz cavity antenna for Martlet IIC projectile

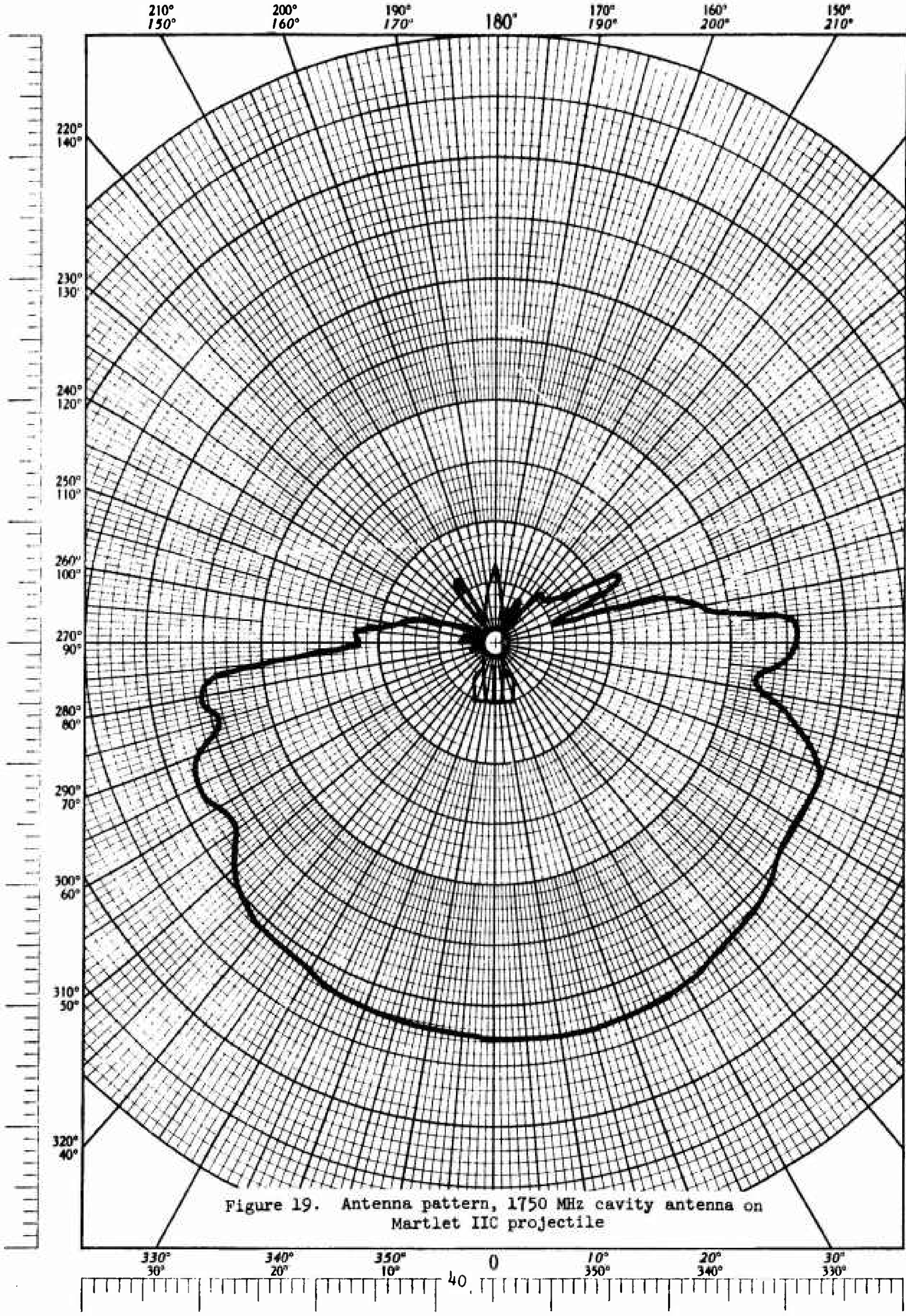


Figure 19. Antenna pattern, 1750 MHz cavity antenna on Martlet IIC projectile

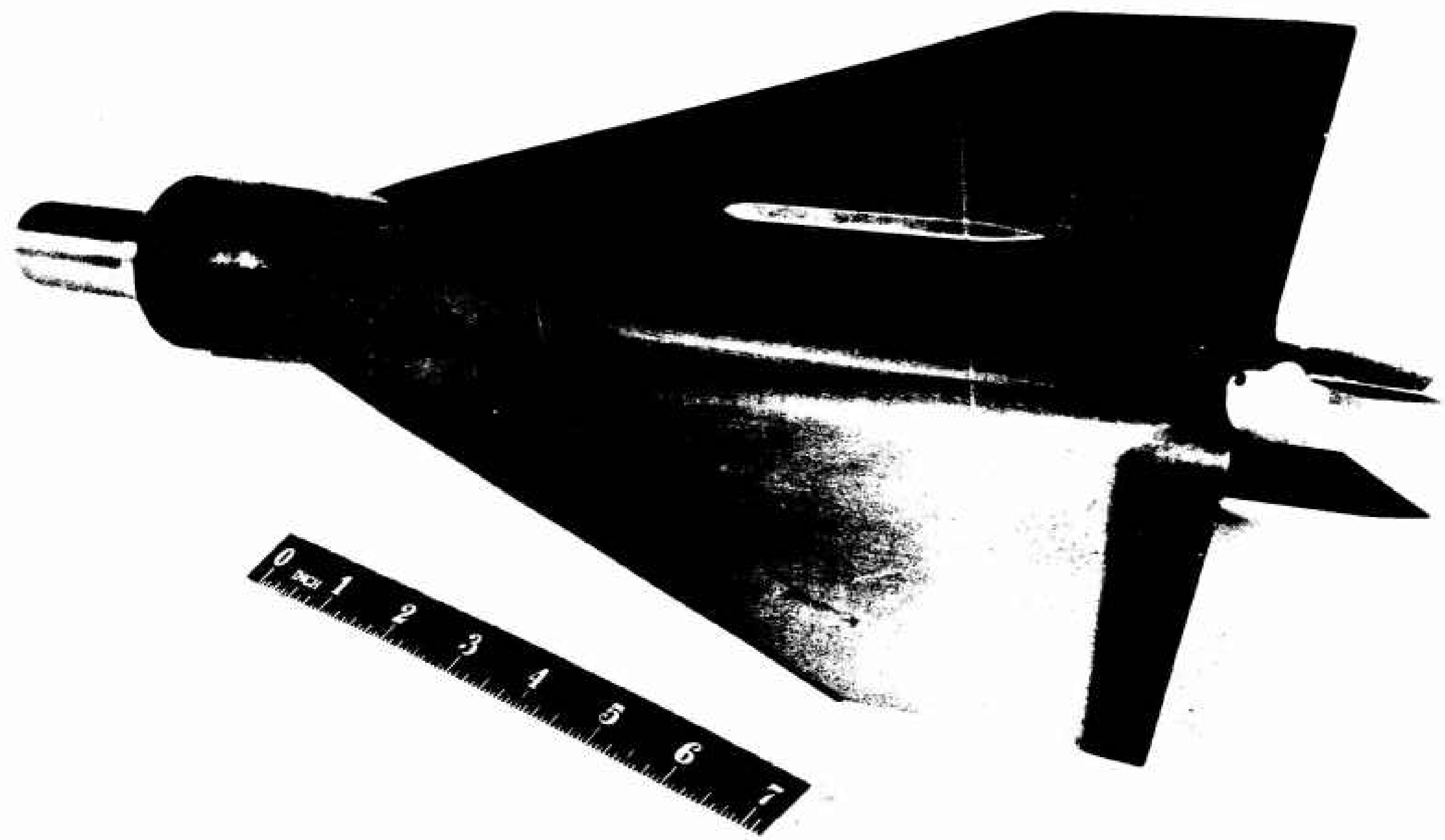


Figure 20. 1750 MHz sloop antenna on 7-inch projectile tail fins

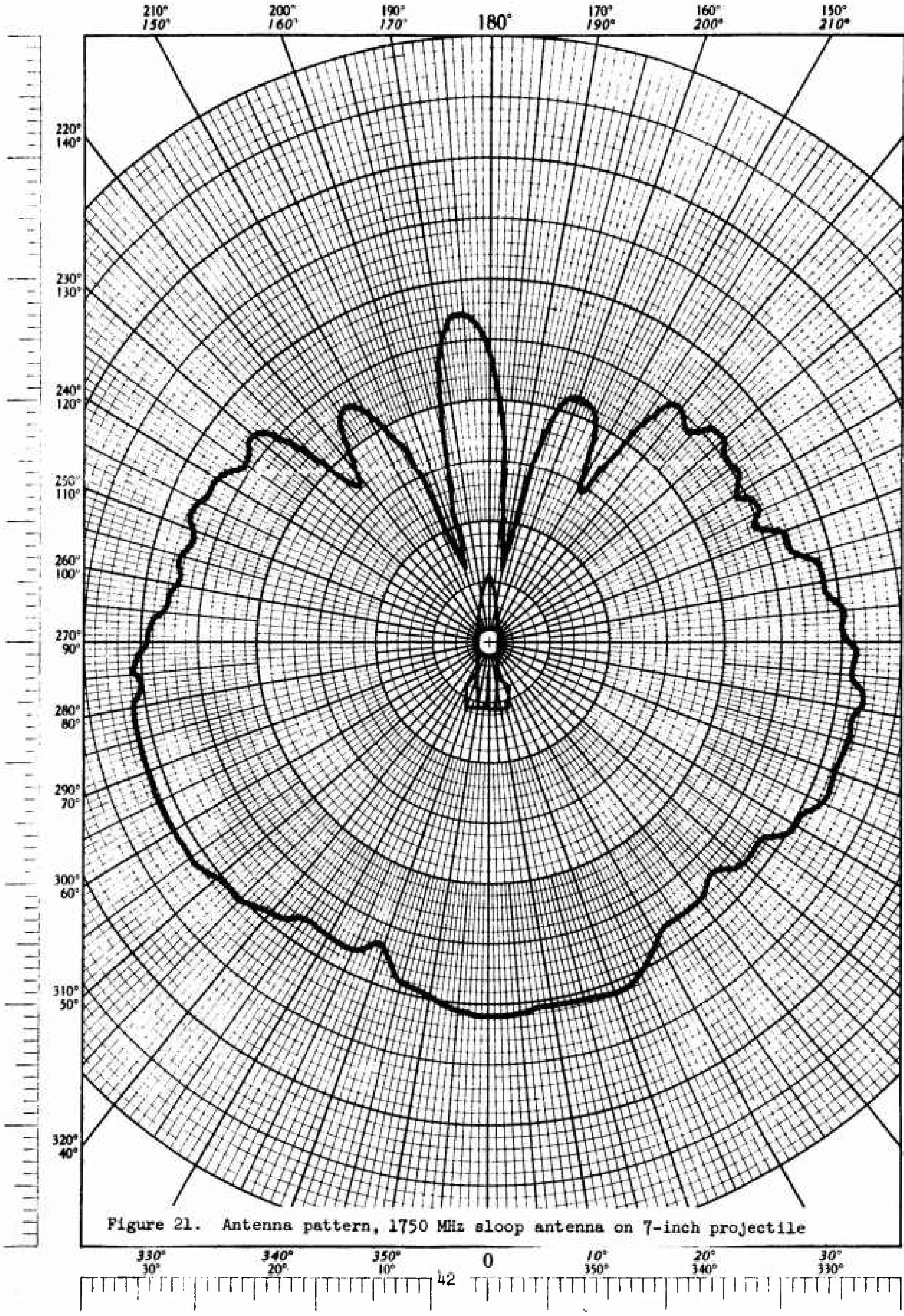


Figure 21. Antenna pattern, 1750 MHz sloop antenna on 7-inch projectile

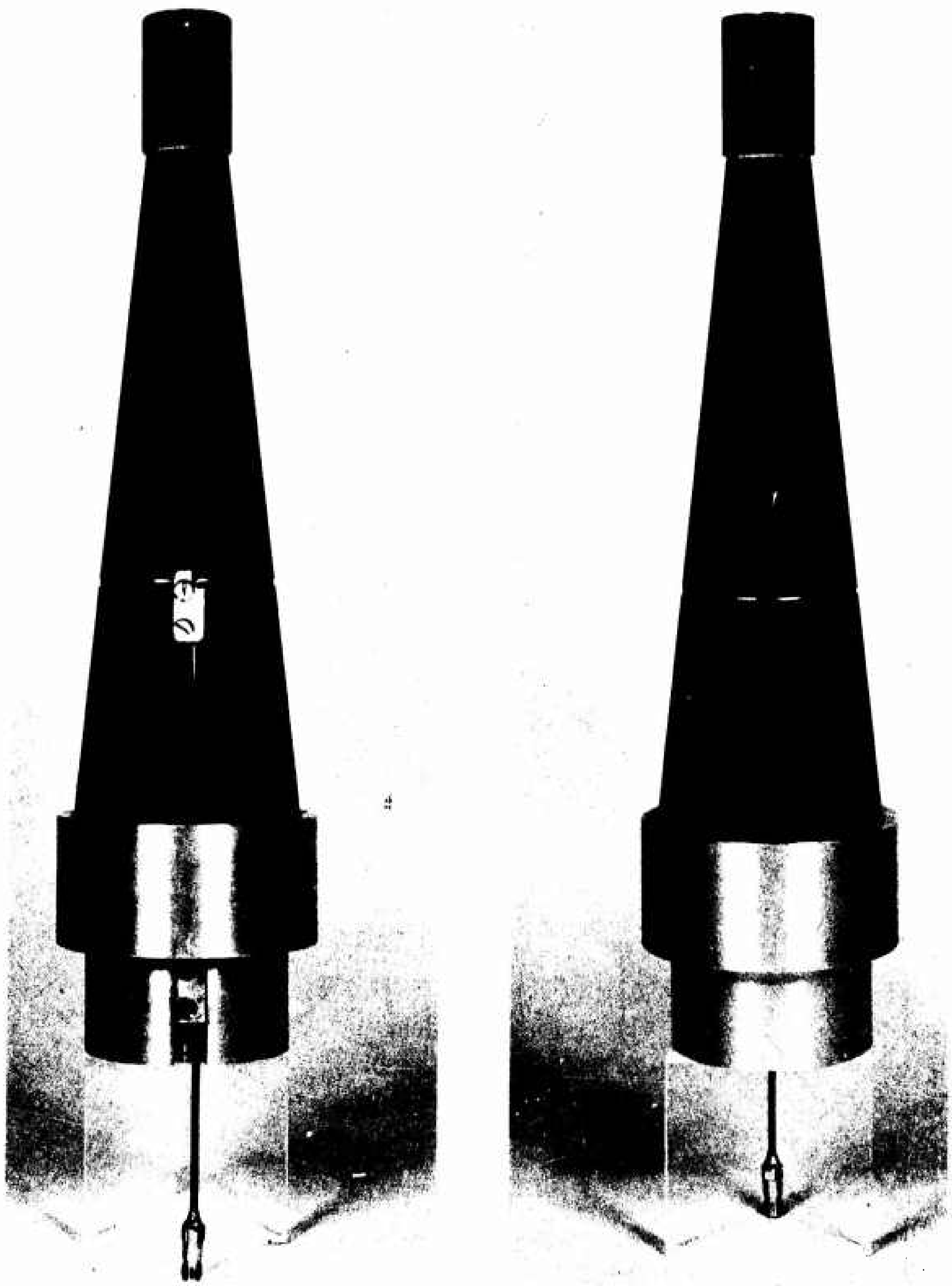


Figure 22. 1750 MHz Halo antenna for 7-inch projectile

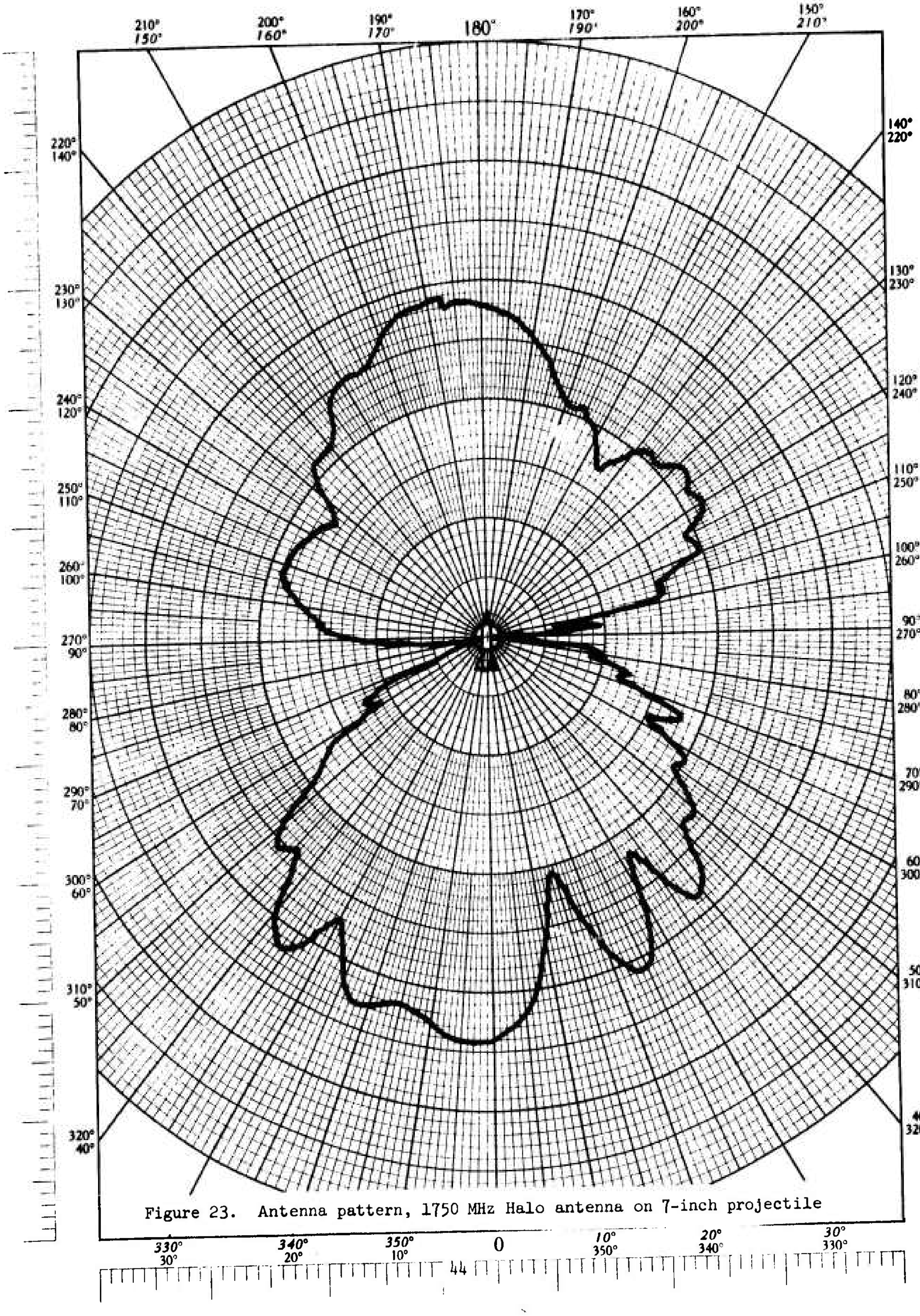


Figure 23. Antenna pattern, 1750 MHz Halo antenna on 7-inch projectile

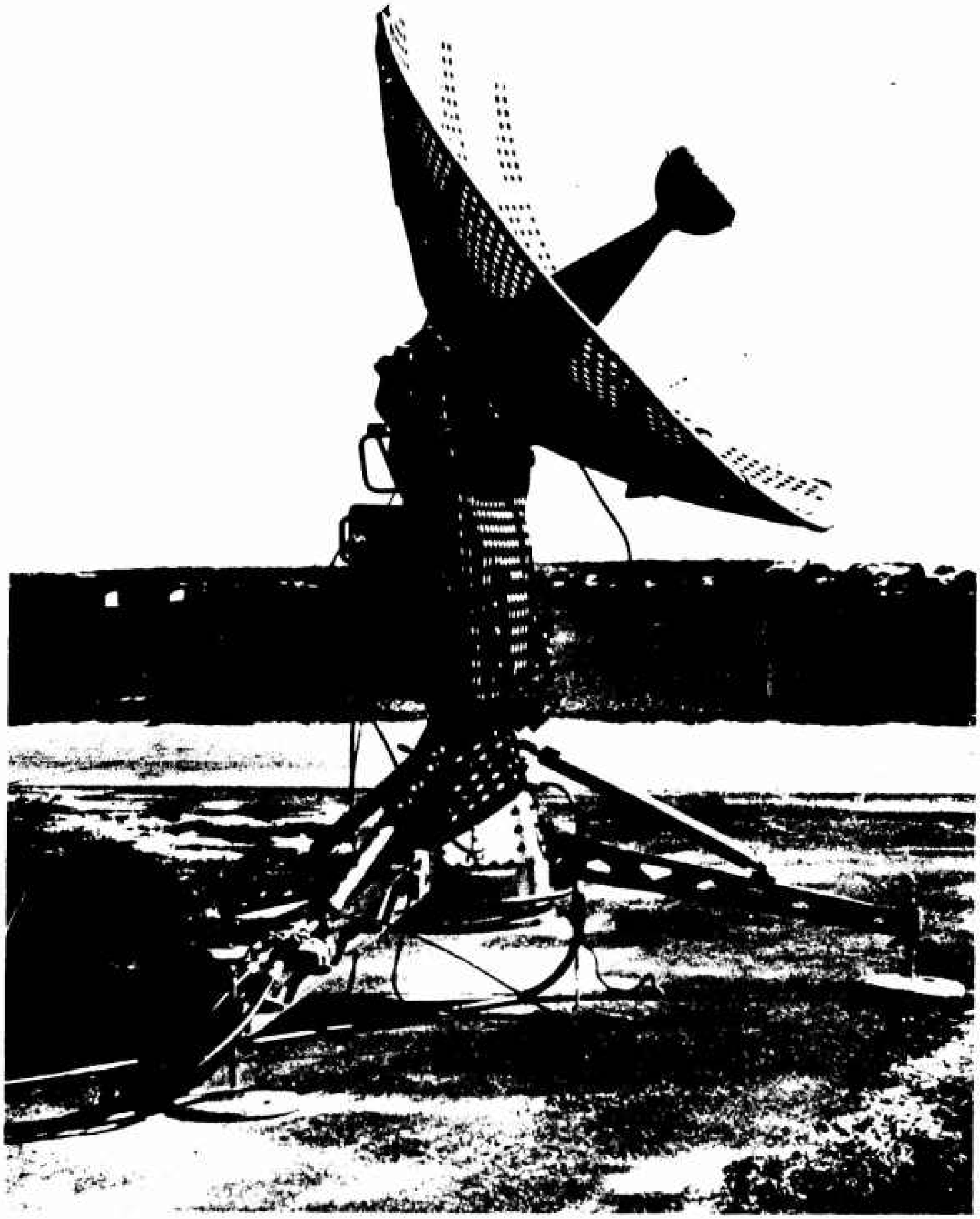


Figure 24. GMD tracking antenna

Figure 25. GMD tracking antenna and recording van

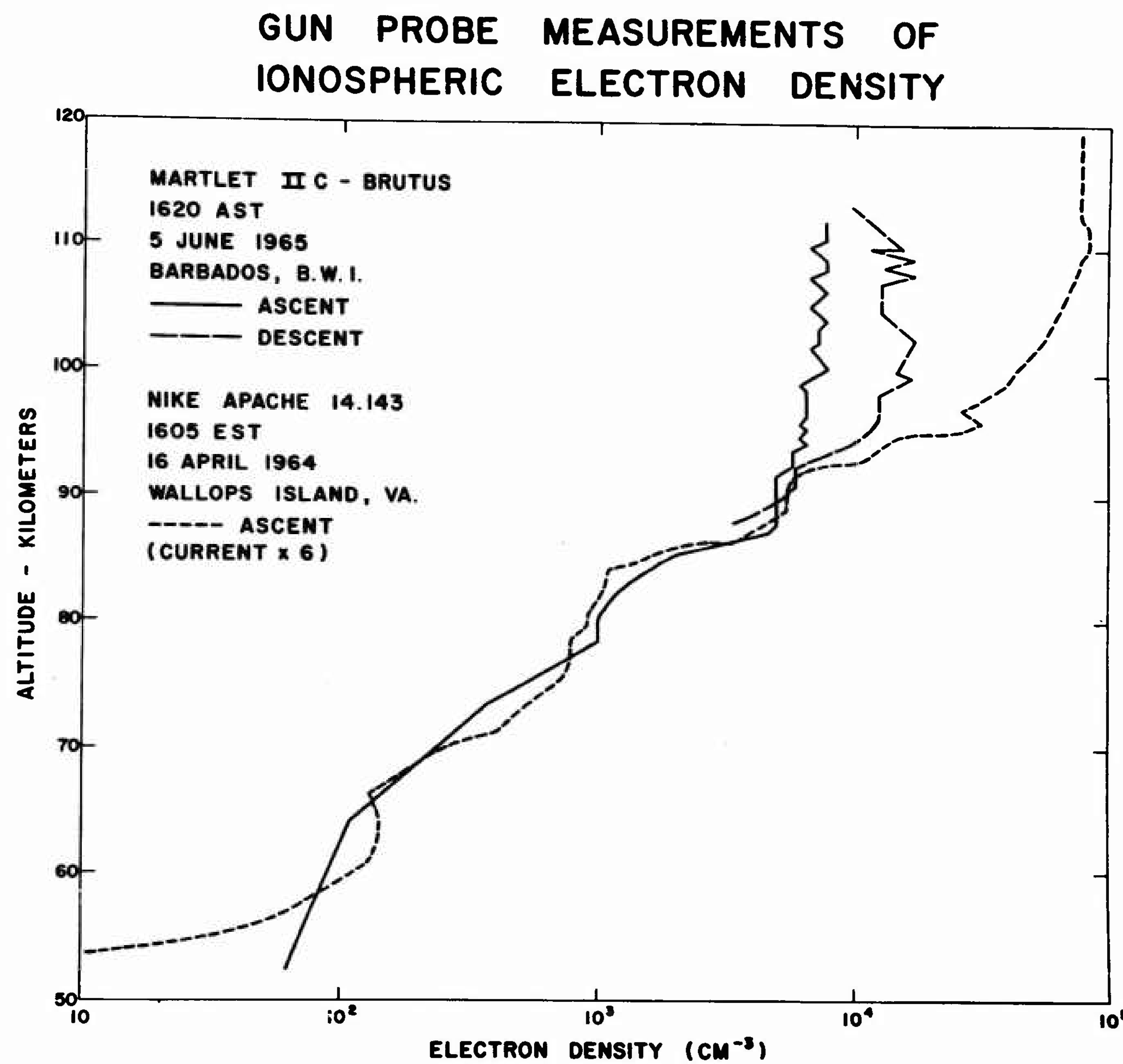


Figure 26. Electron density vs altitude - Brutus

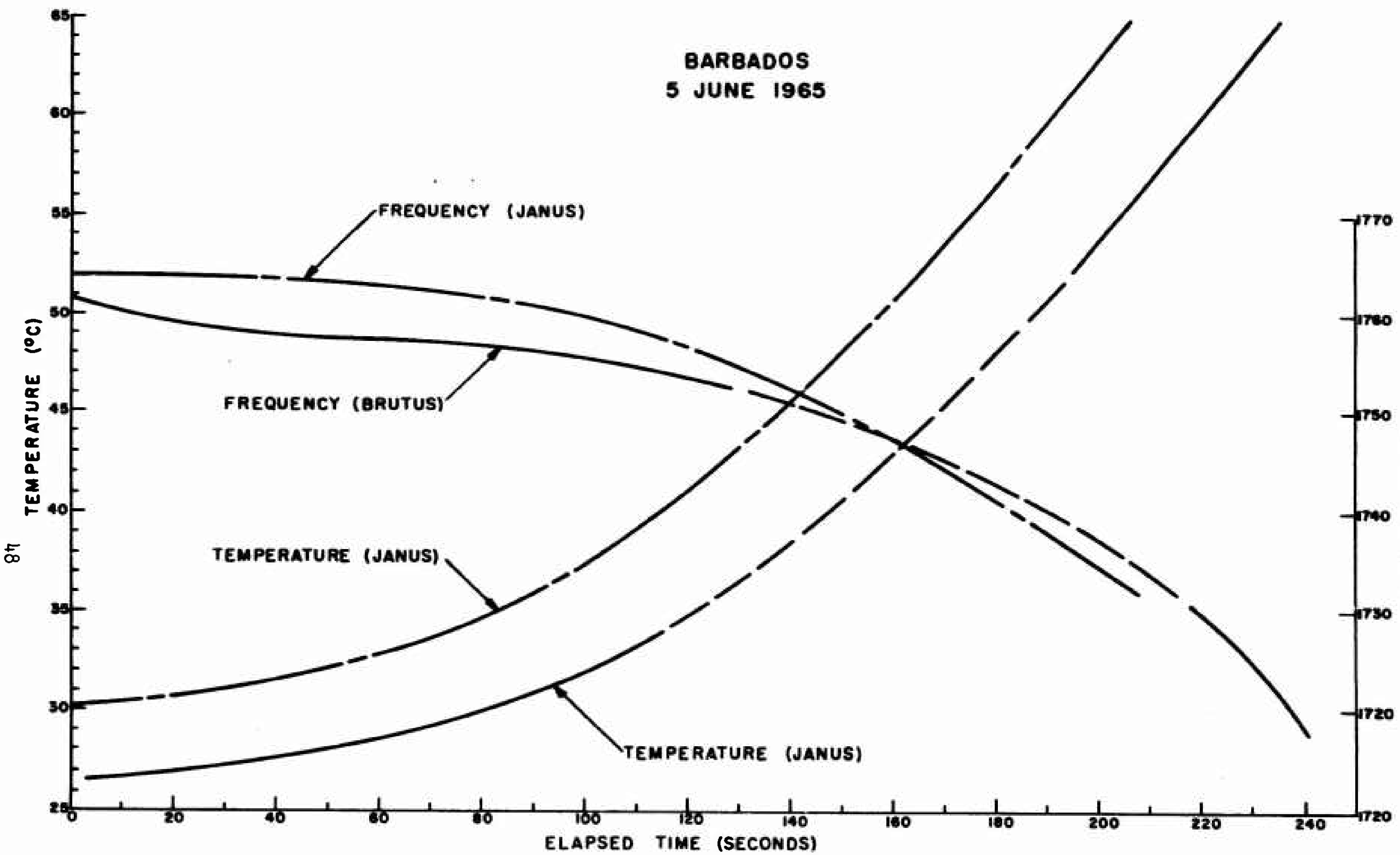


Figure 27. Frequency and temperature vs time - Brutus, Janus

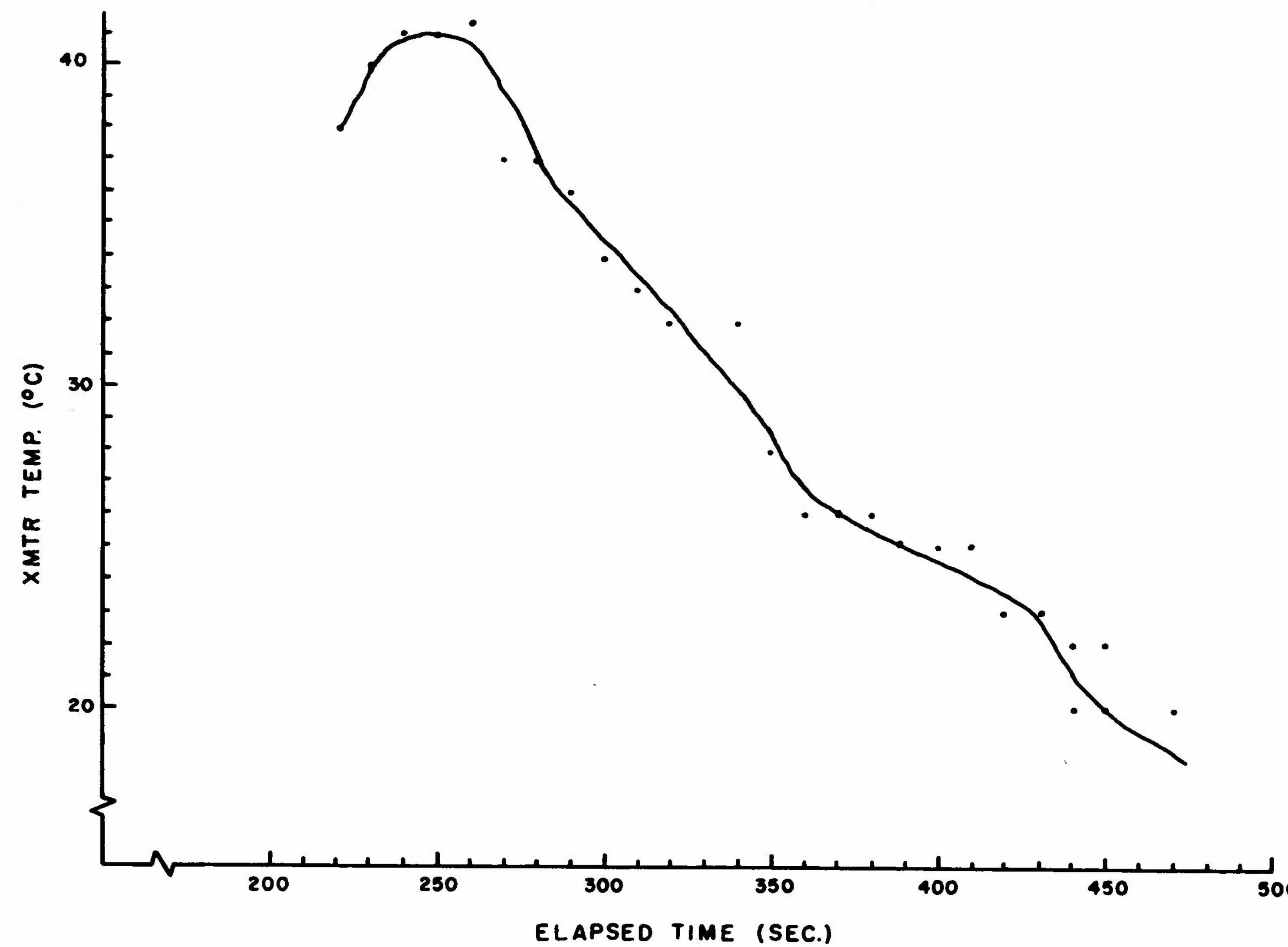
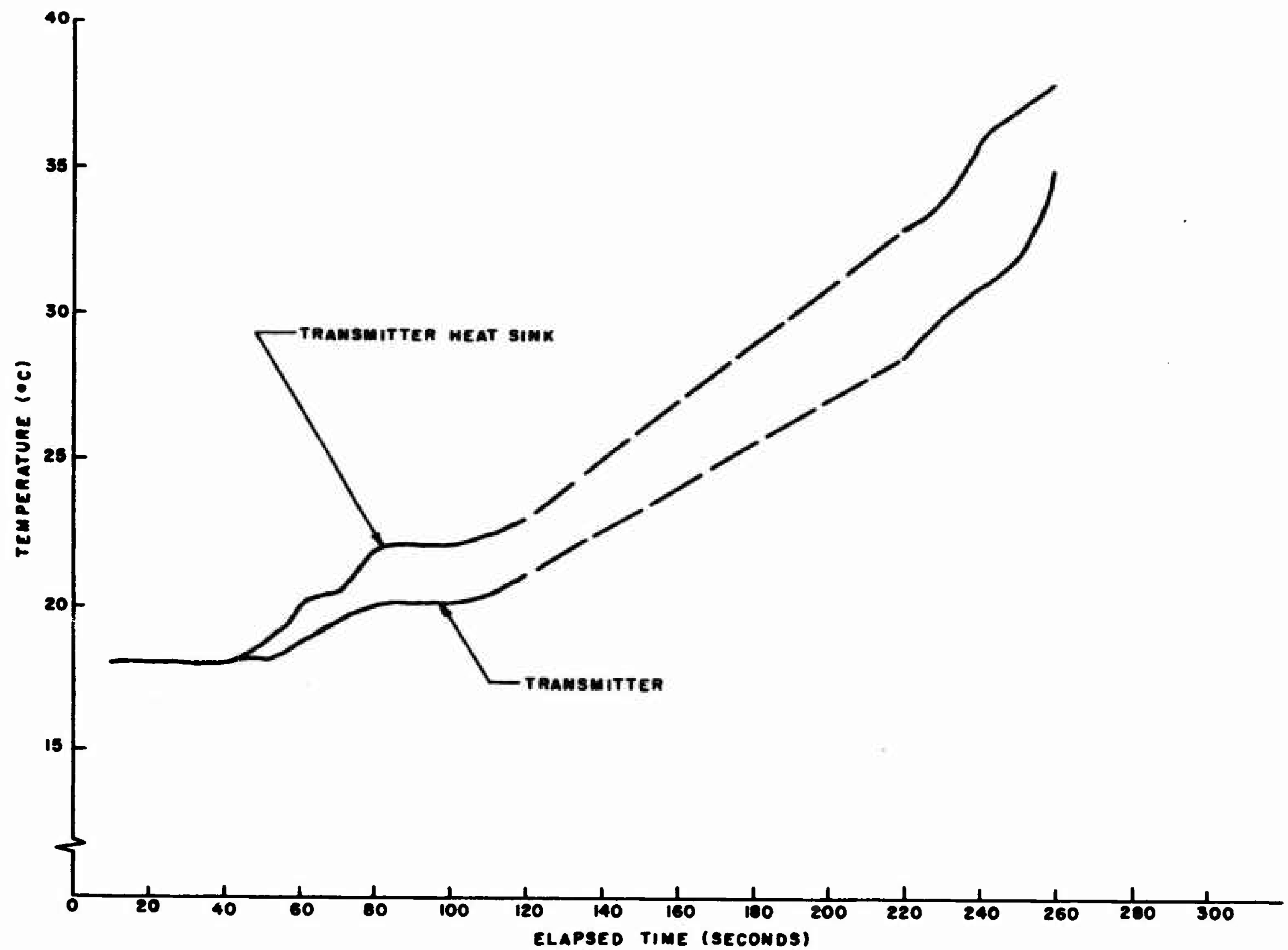


Figure 28. Temperature vs time - Kendall



7" GUN PROBE (#3) FIRED 15 DEC. 1965 WALLOPS ISLAND, VA.

Figure 29. Temperature vs time - $E_1 2446$

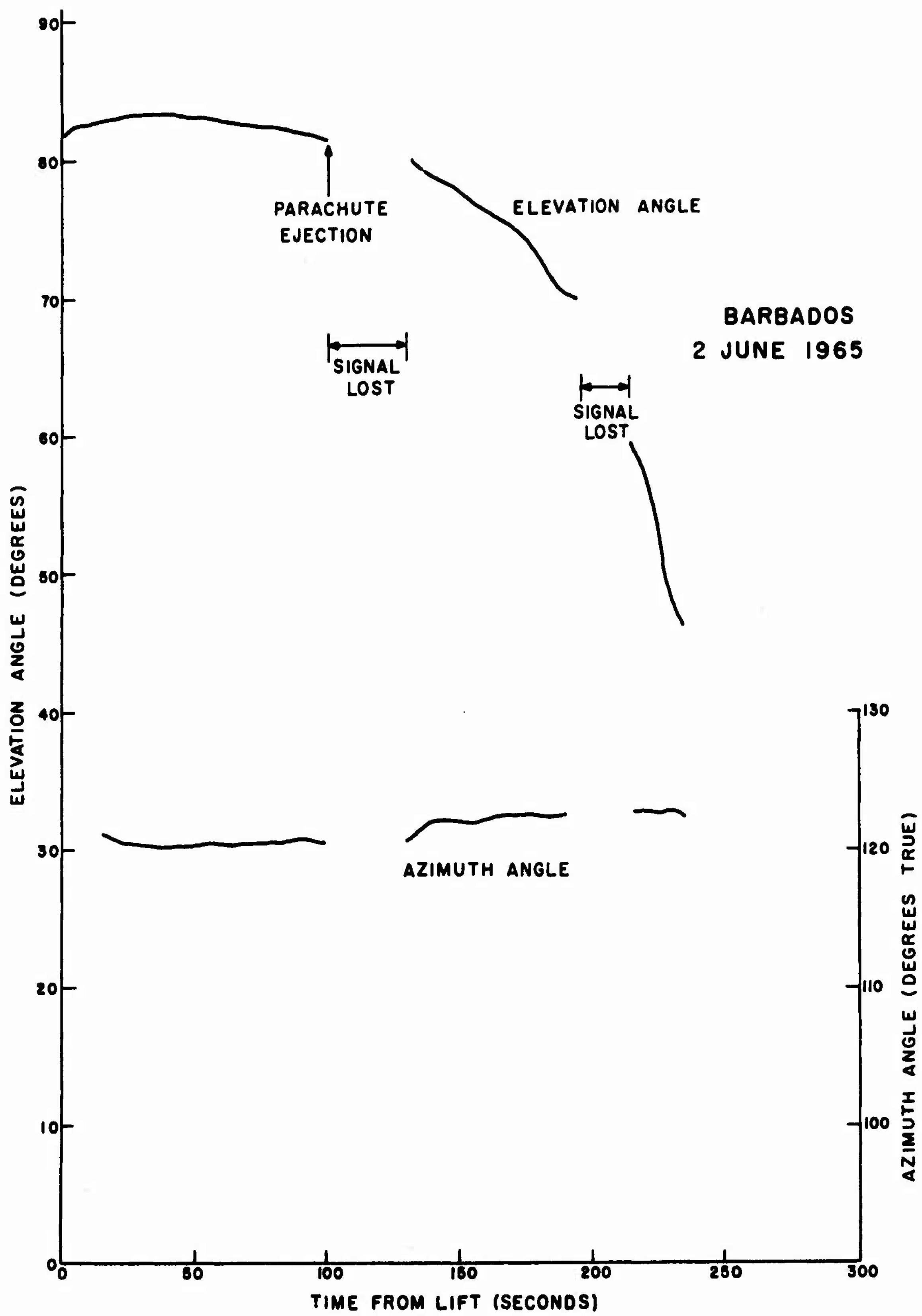


Figure 30. GMD azimuth & elevation angles vs time - Rufus

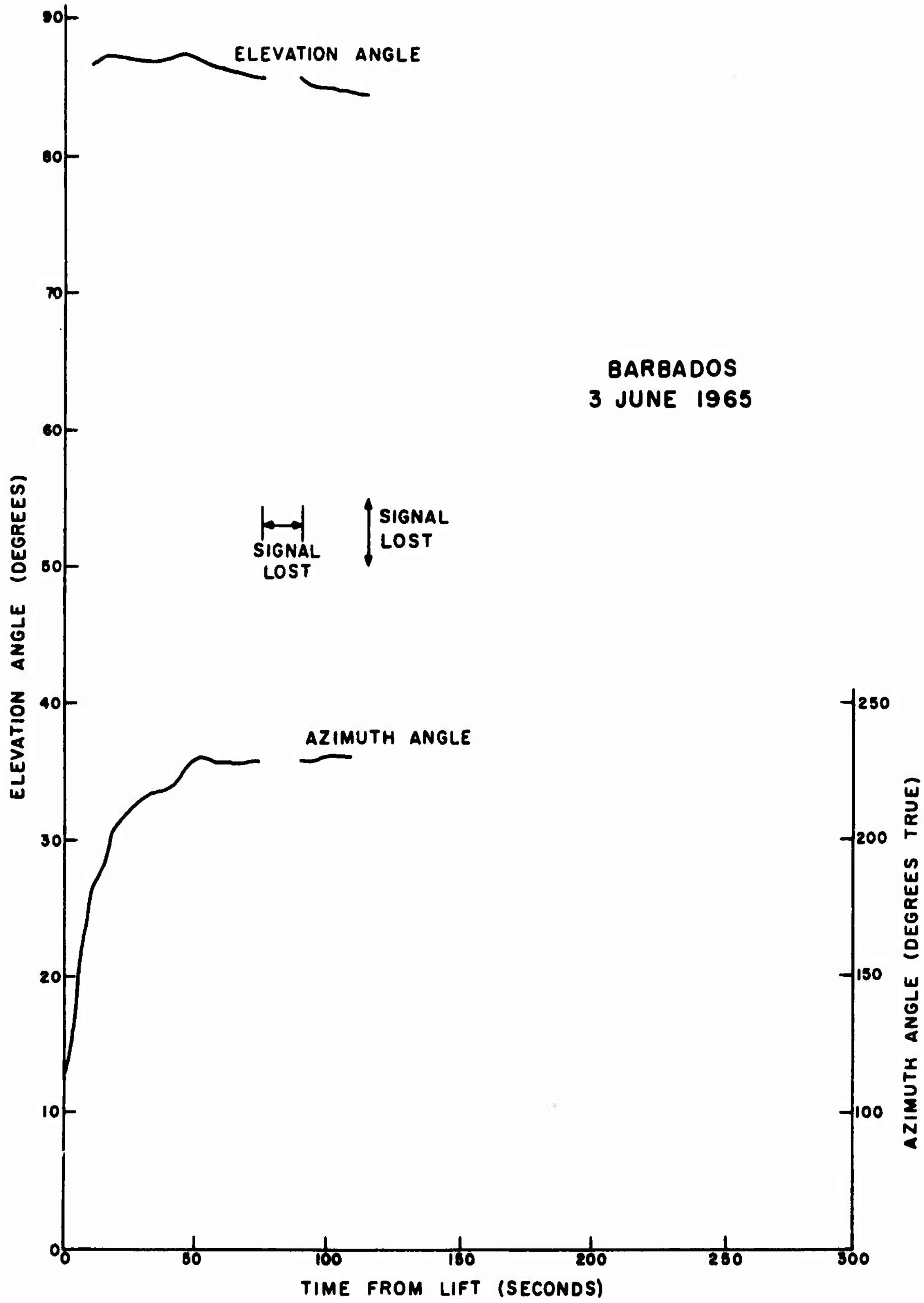


Figure 31. GMD azimuth & elevation angles vs time - IRE

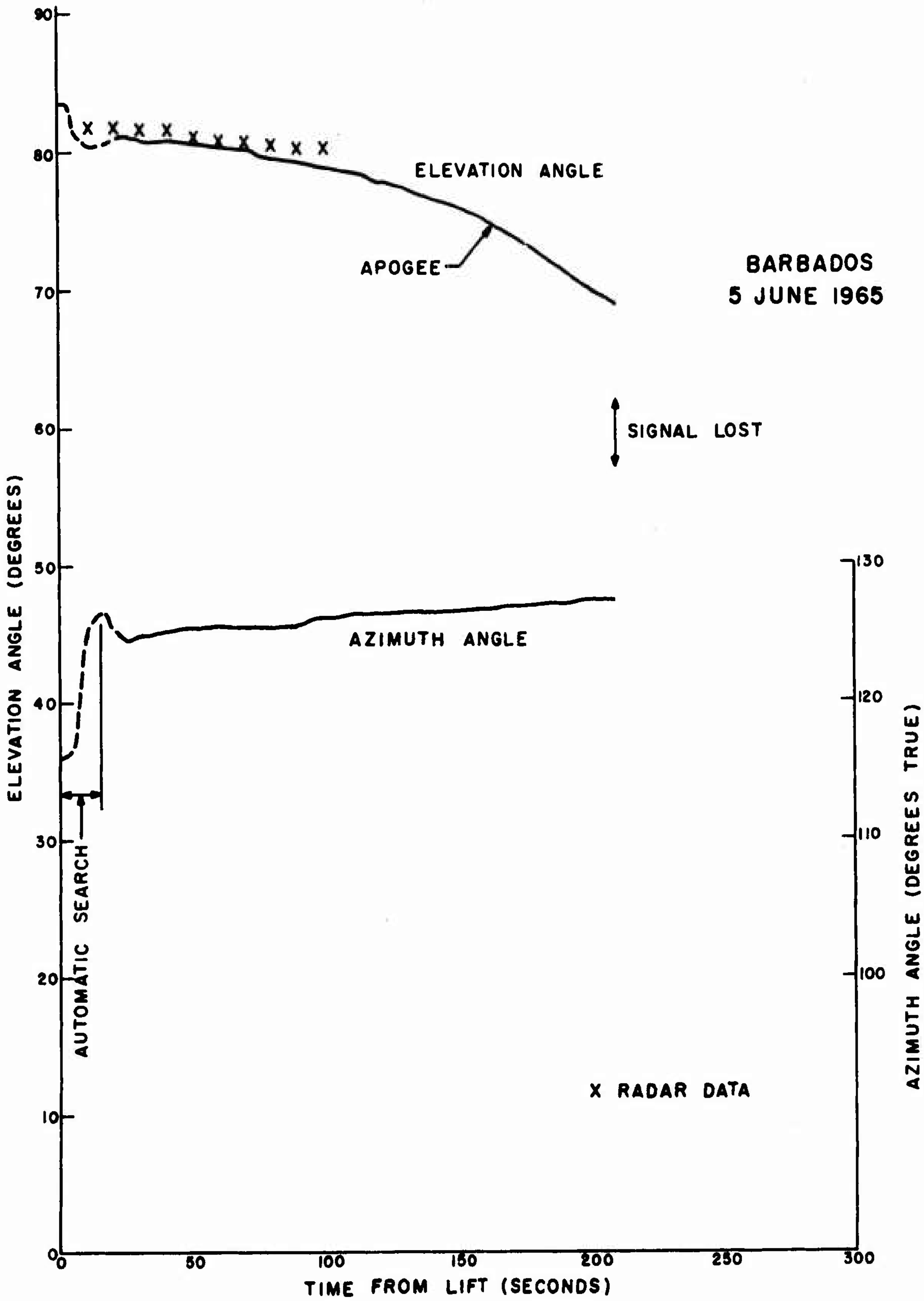


Figure 32. GMD azimuth & elevation angles vs time - Janus

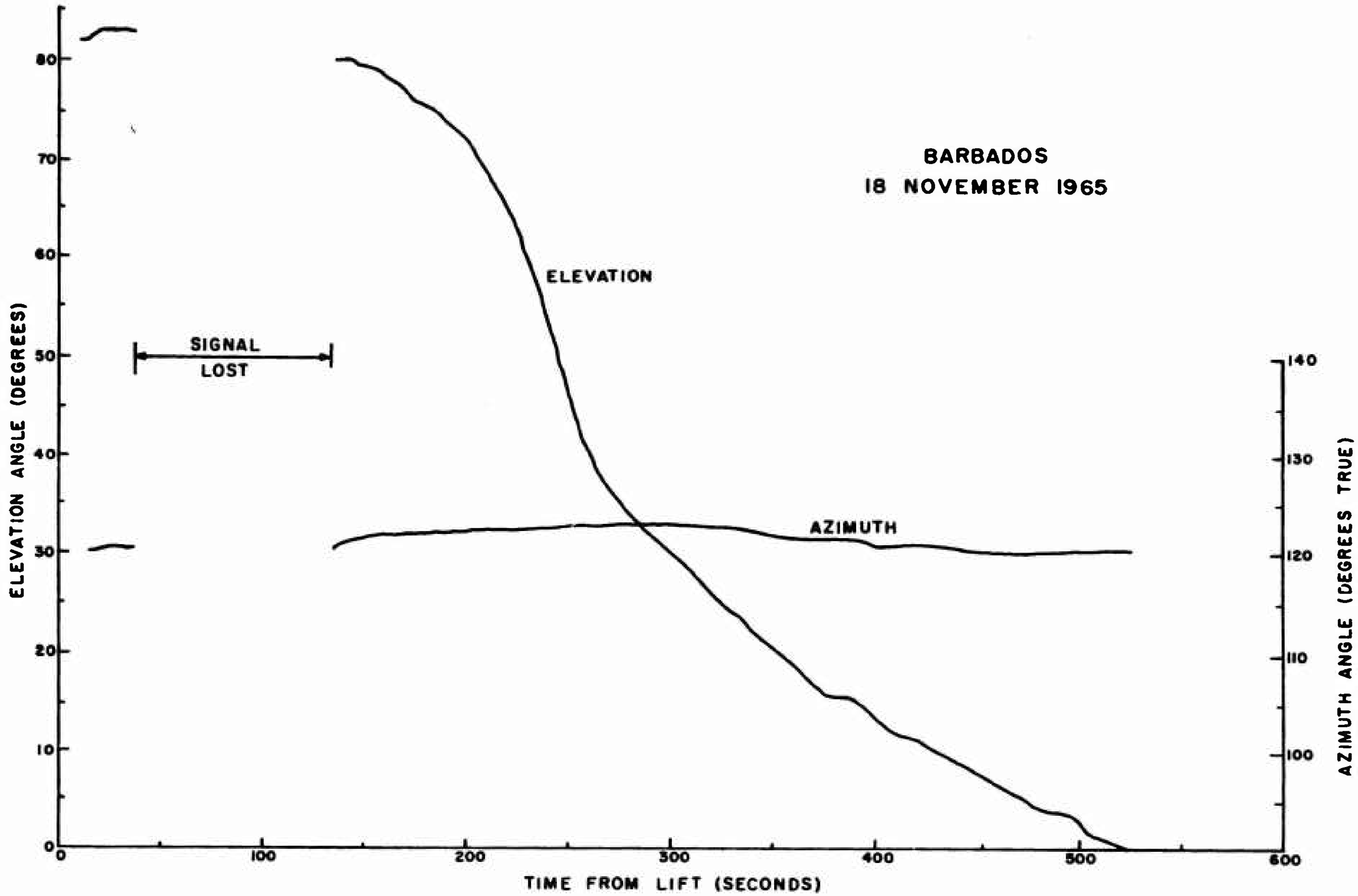


Figure 33. GMD azimuth & elevation angles vs time - Bridgetown

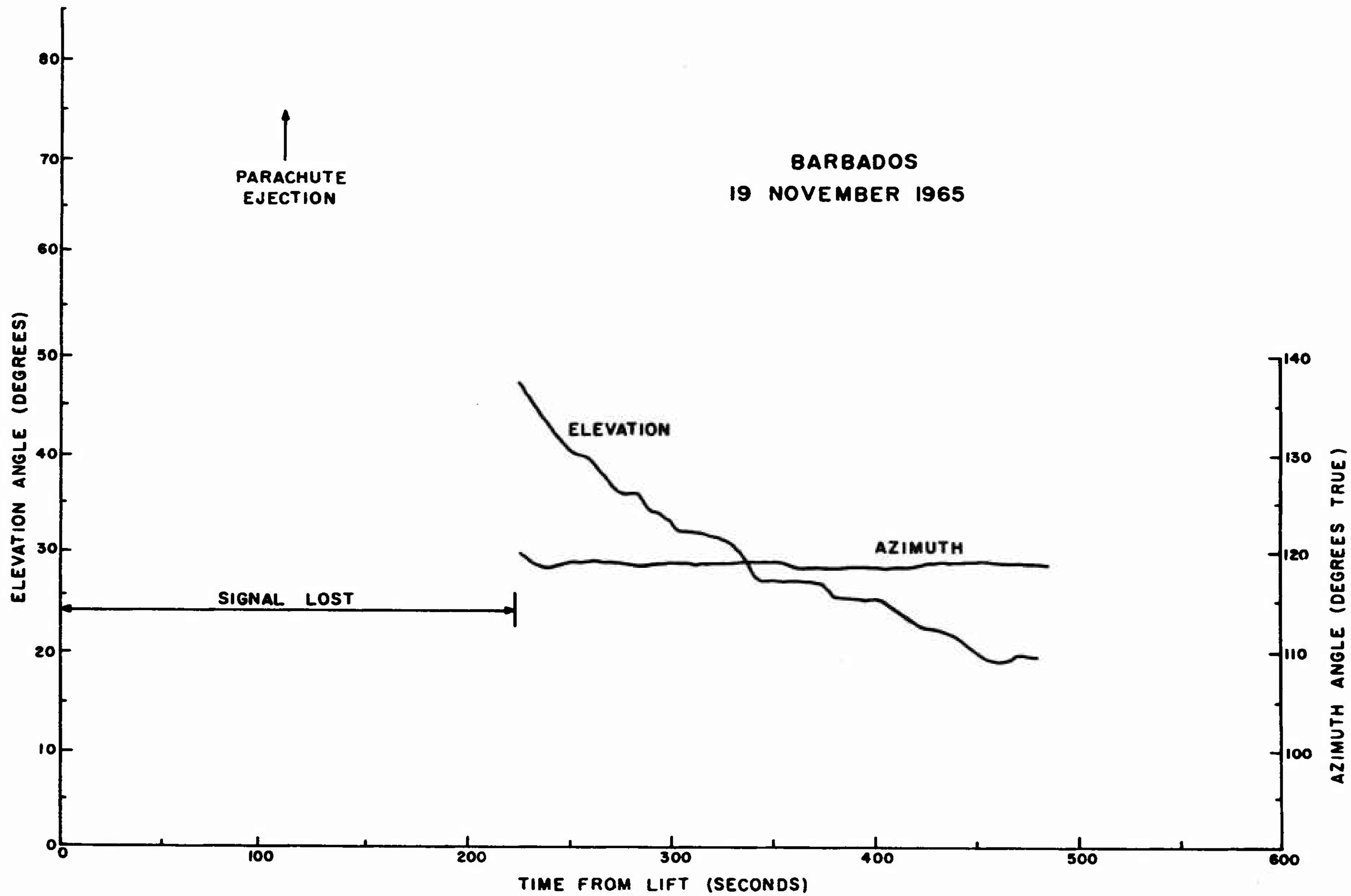


Figure 34. GMD azimuth & elevation angles vs time - Kendall

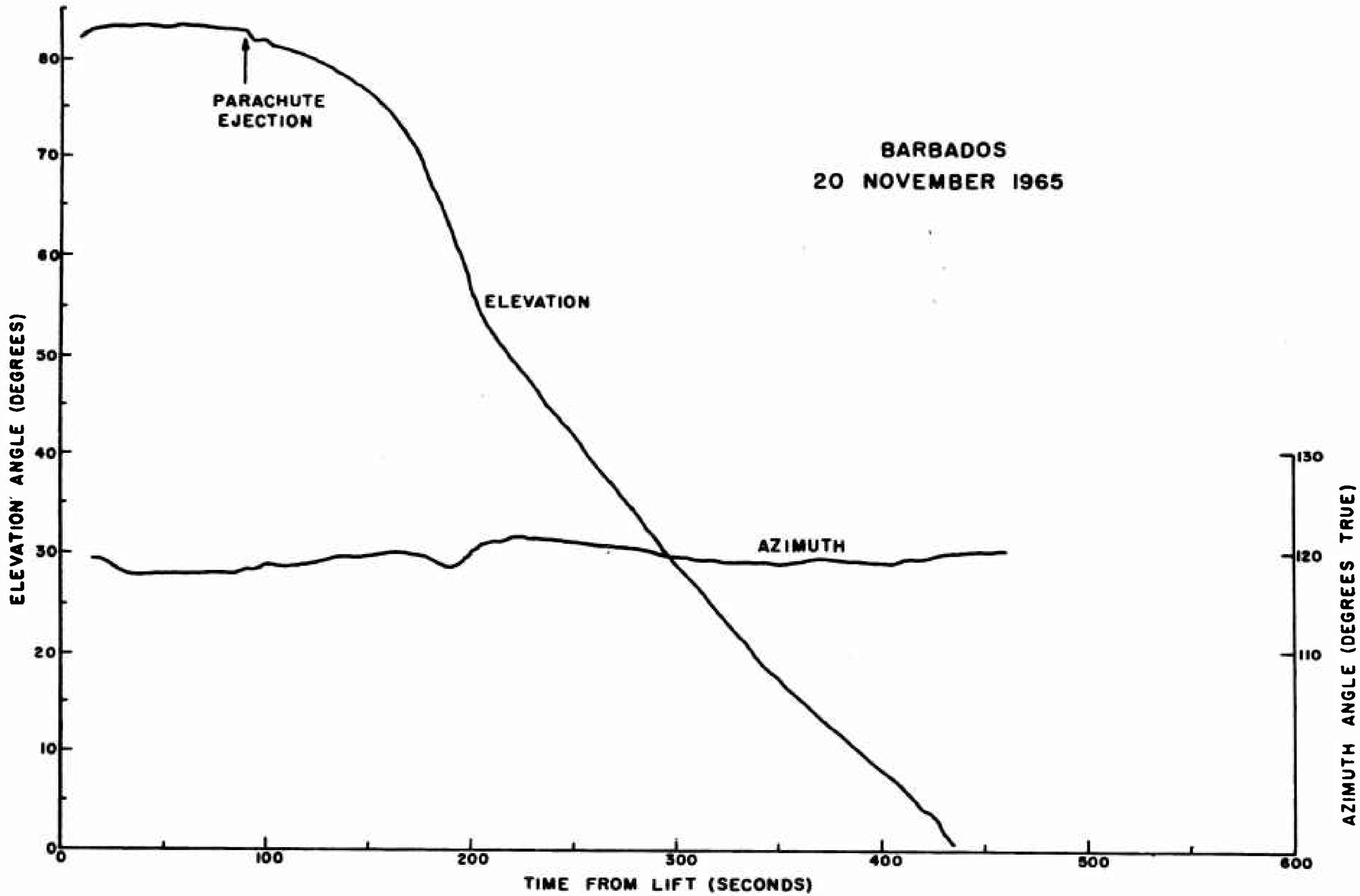


Figure 35. GMD azimuth & elevation angles vs time - Lancaster

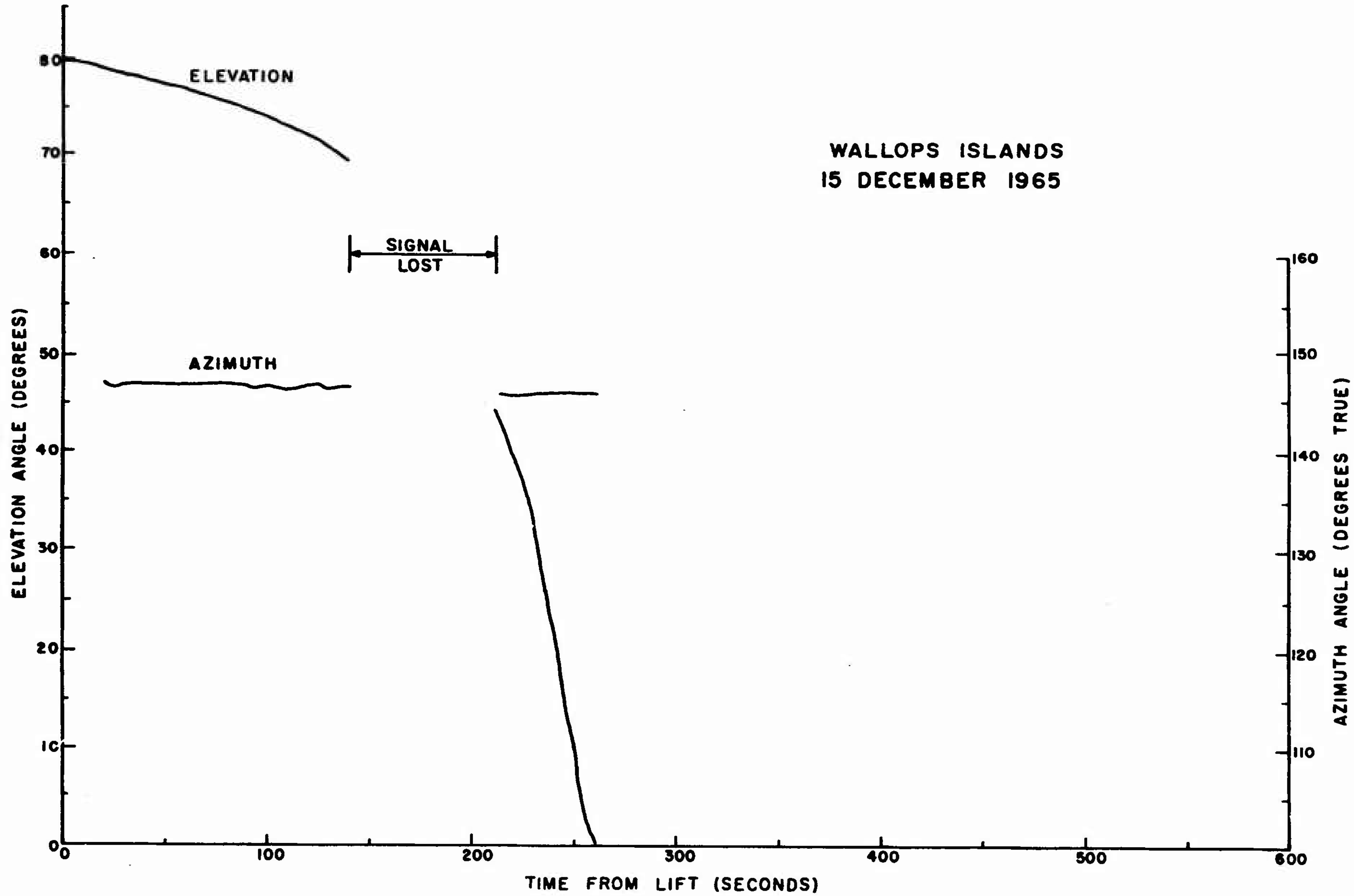


Figure 36. GMD azimuth & elevation angles vs time - $E_1 2446$

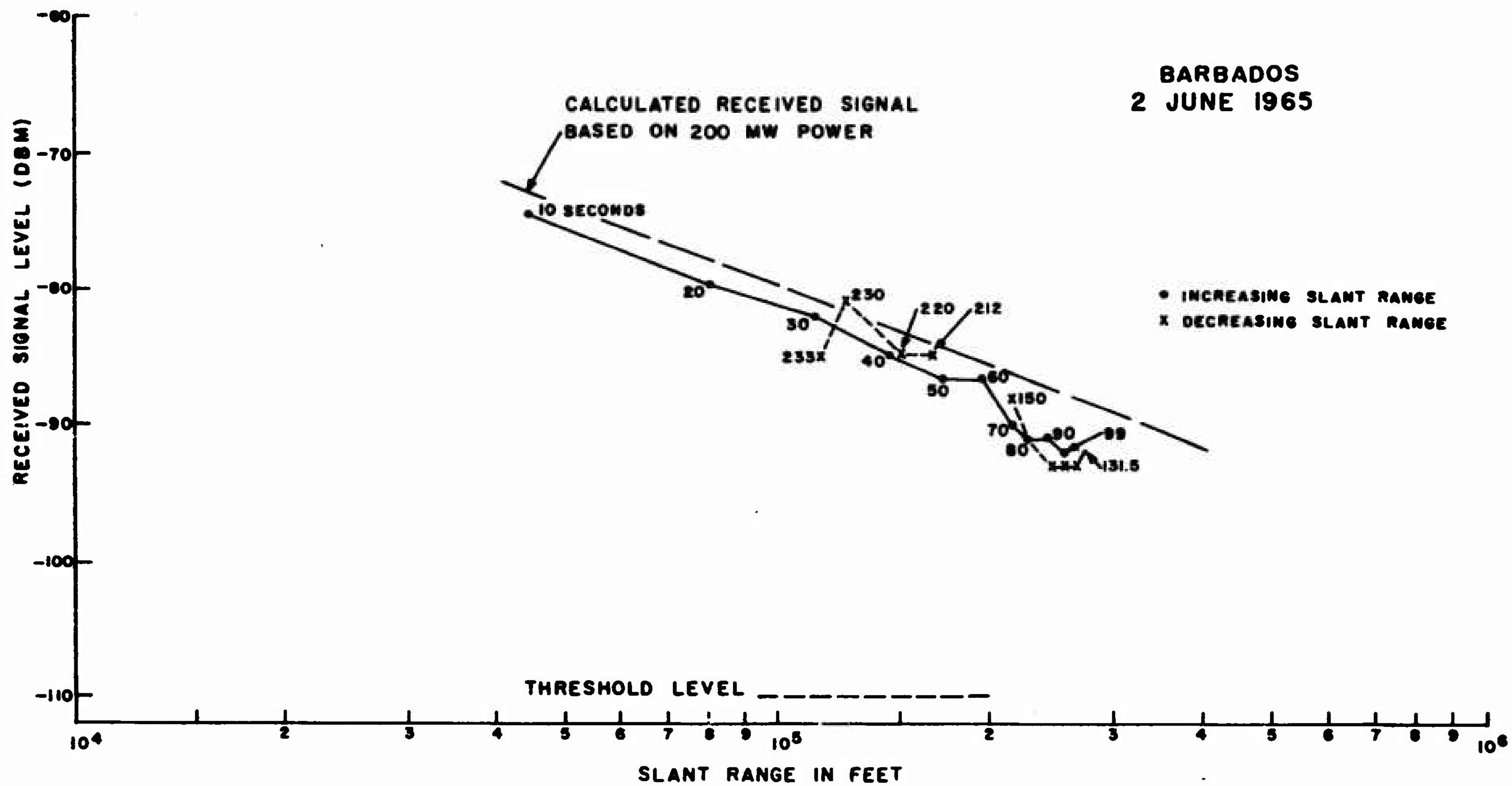


Figure 37. Received signal level vs slant range - Rufus

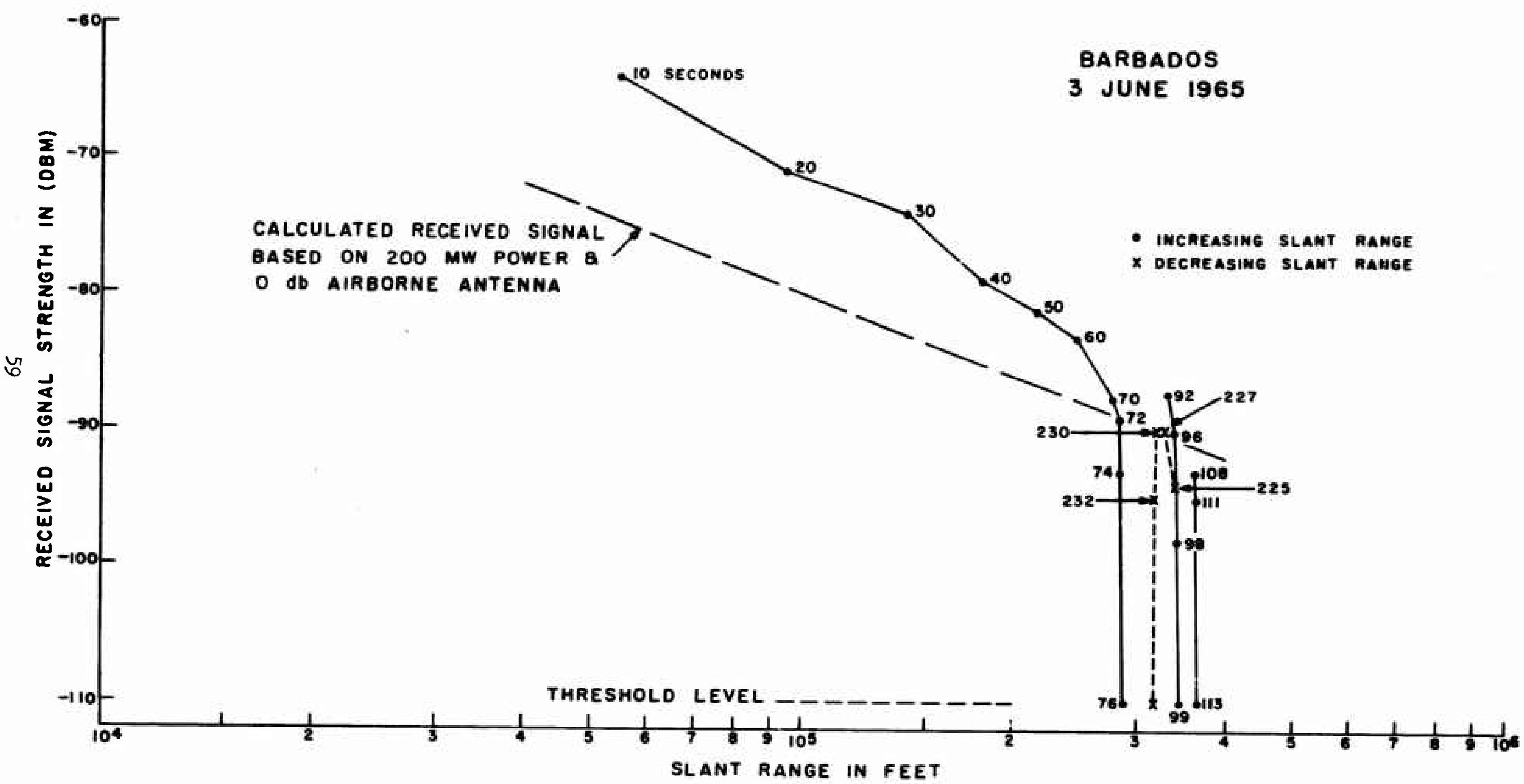


Figure 38. Received signal level vs slant range - IRE

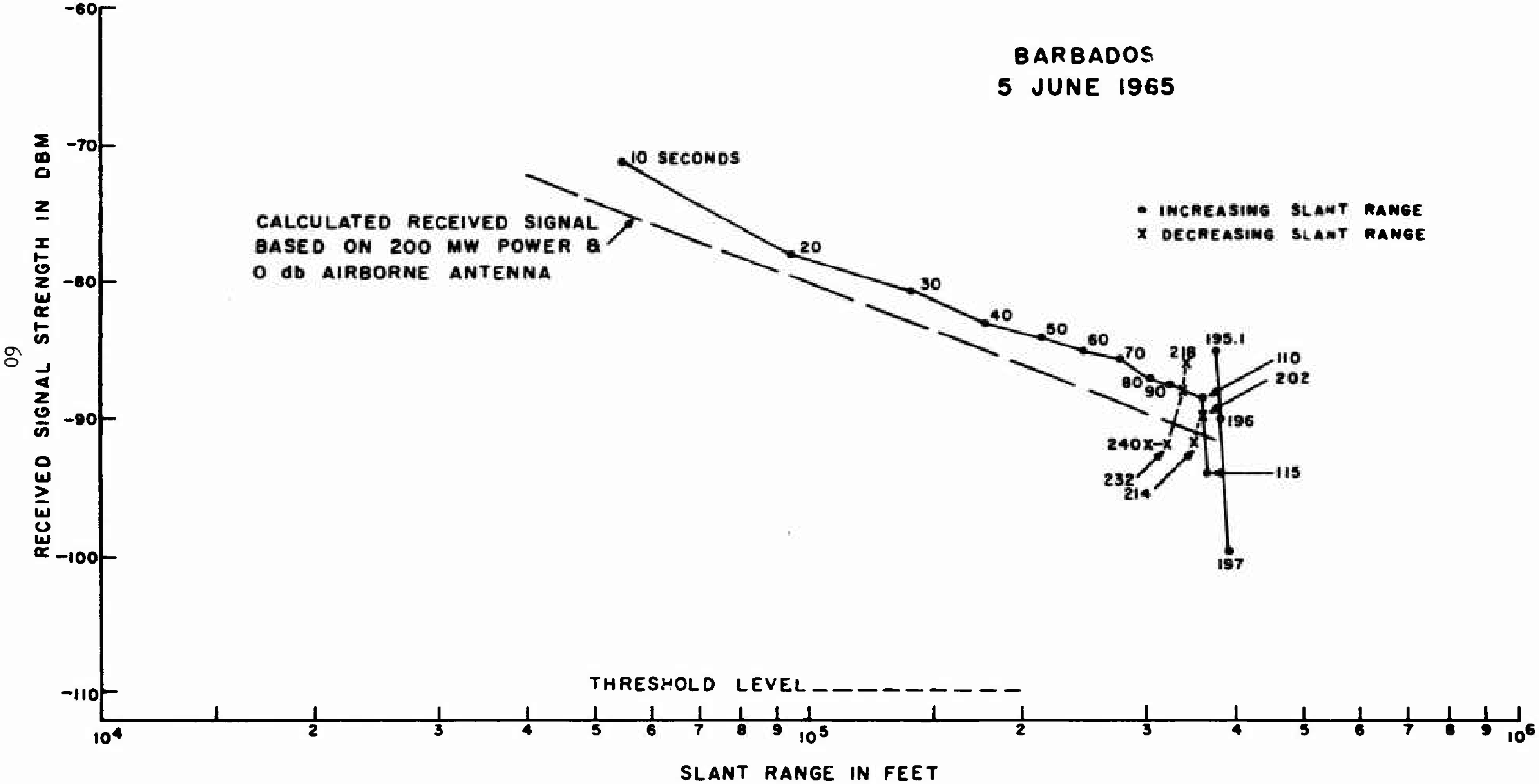


Figure 39. Received signal level vs slant range - Brutus

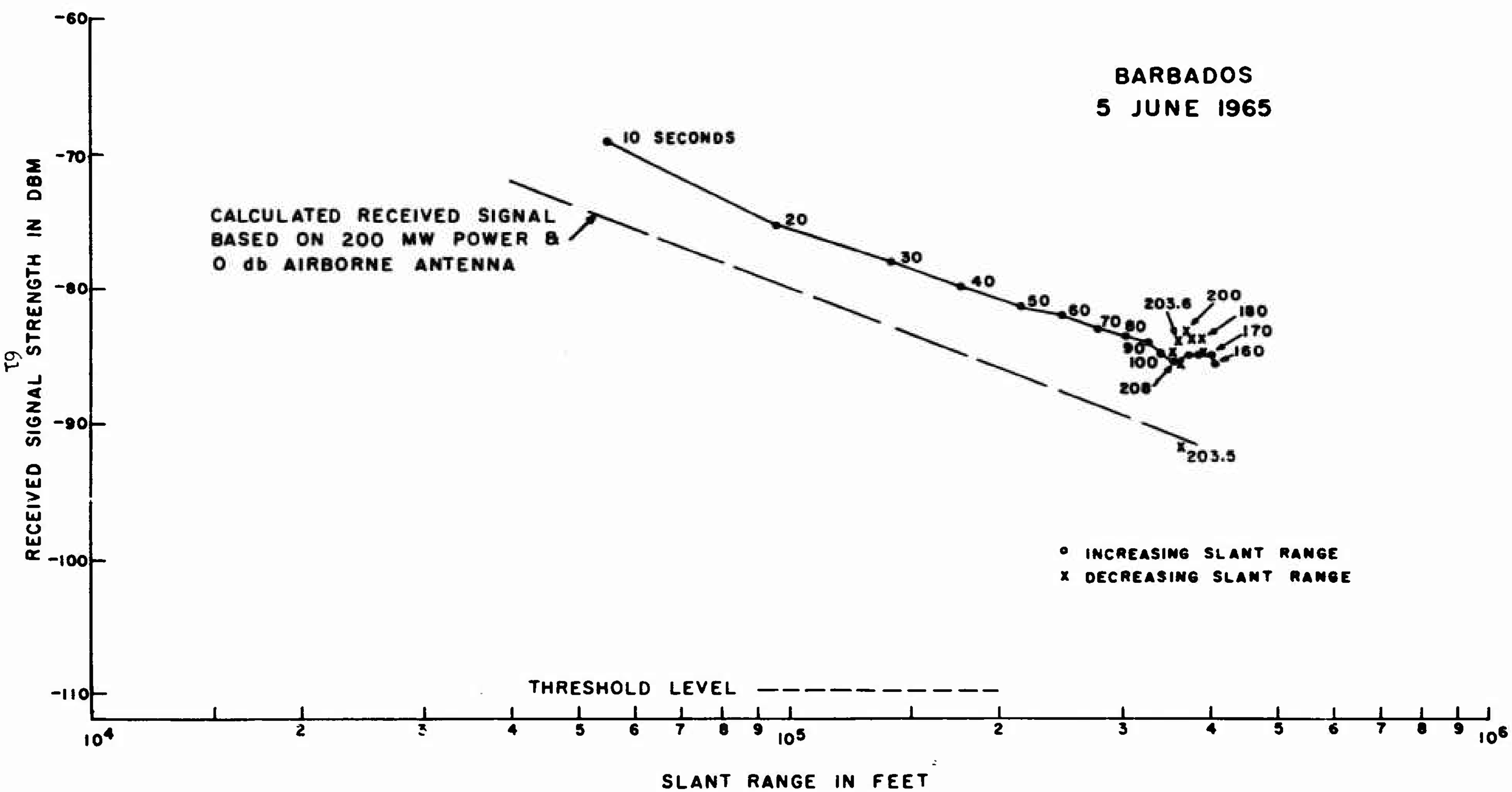


Figure 40. Received signal level vs slant range - Janus

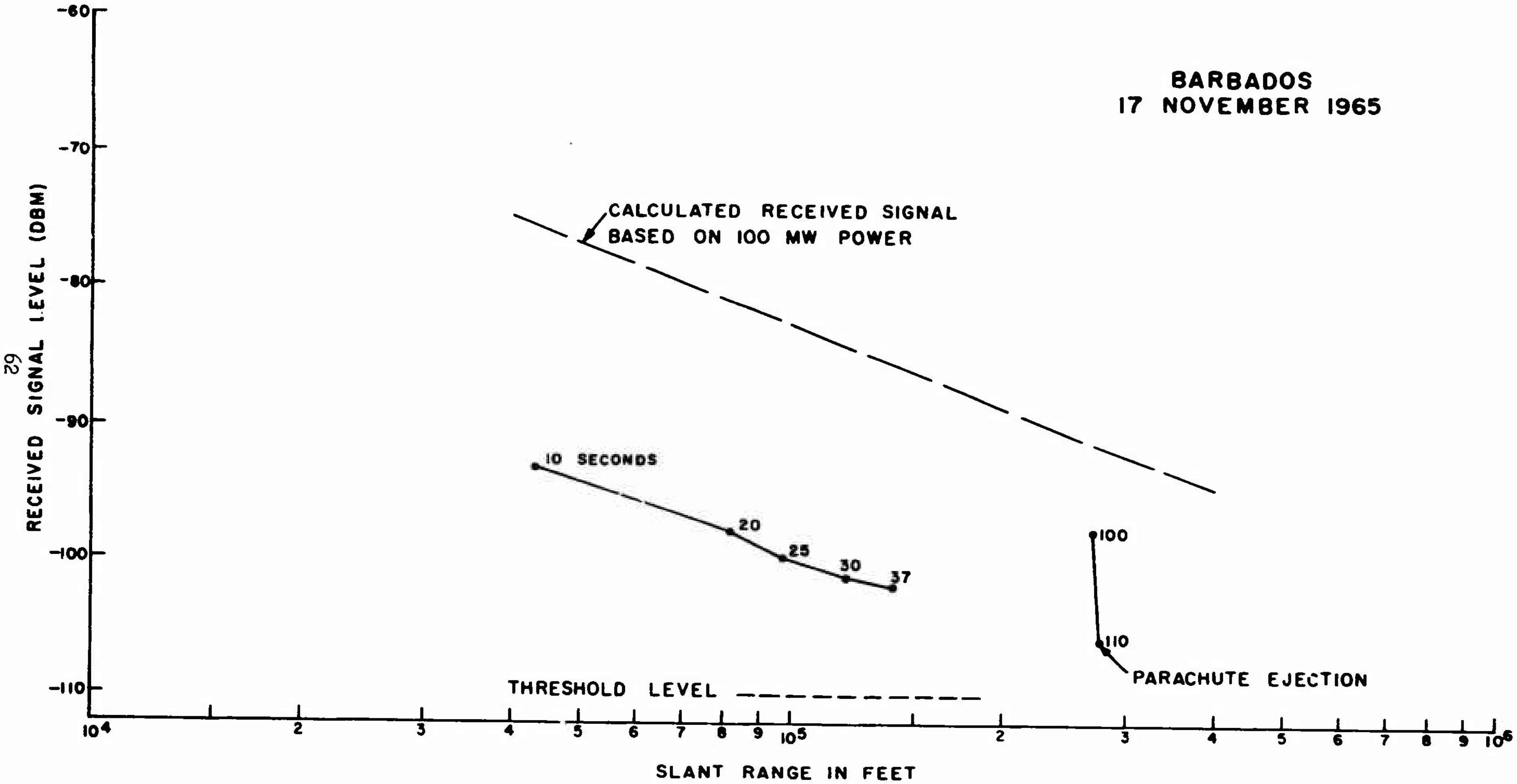


Figure 41. Received signal level vs slant range - Bridgetown

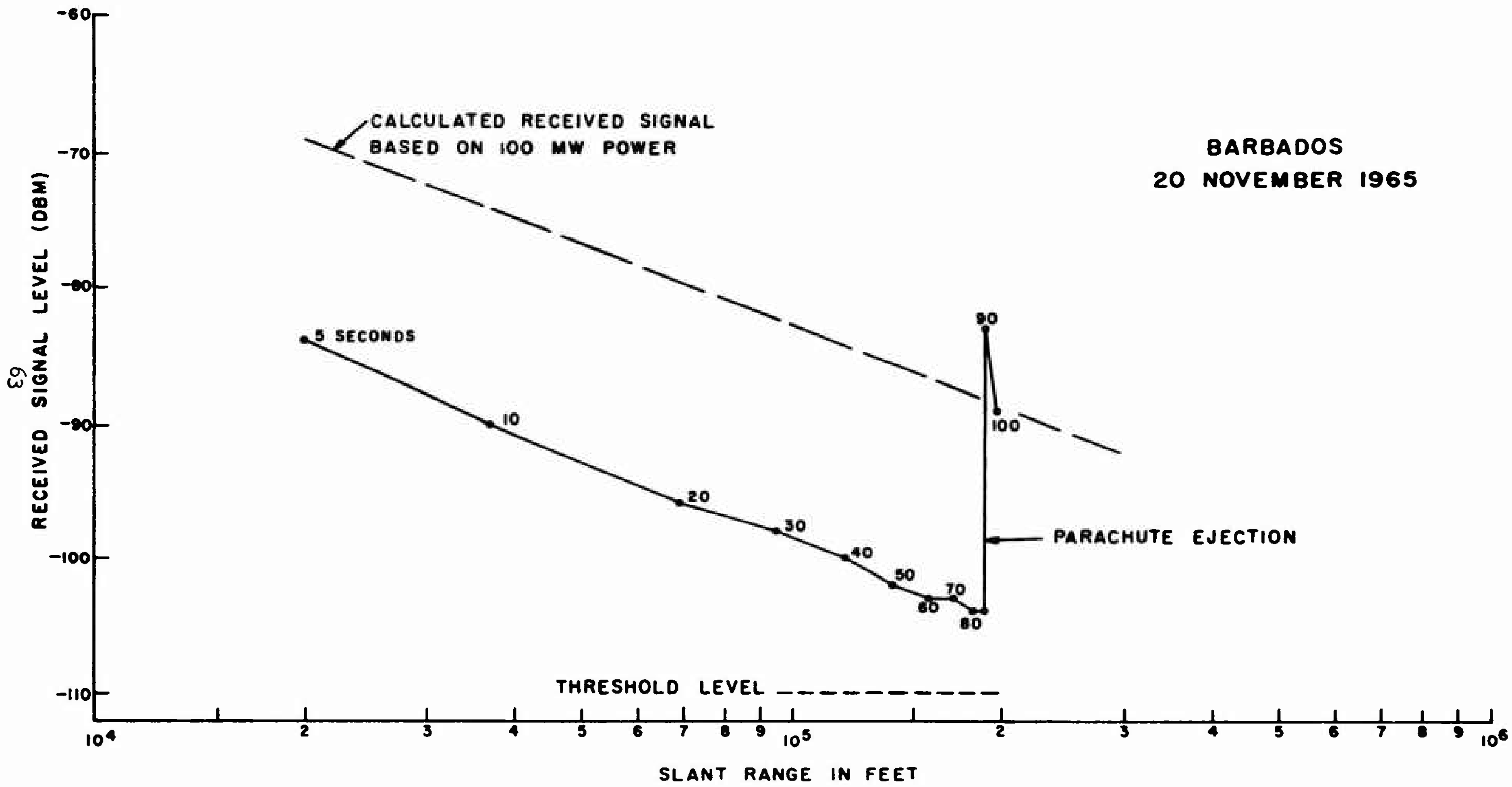


Figure 42. Received signal level vs slant range - Lancaster

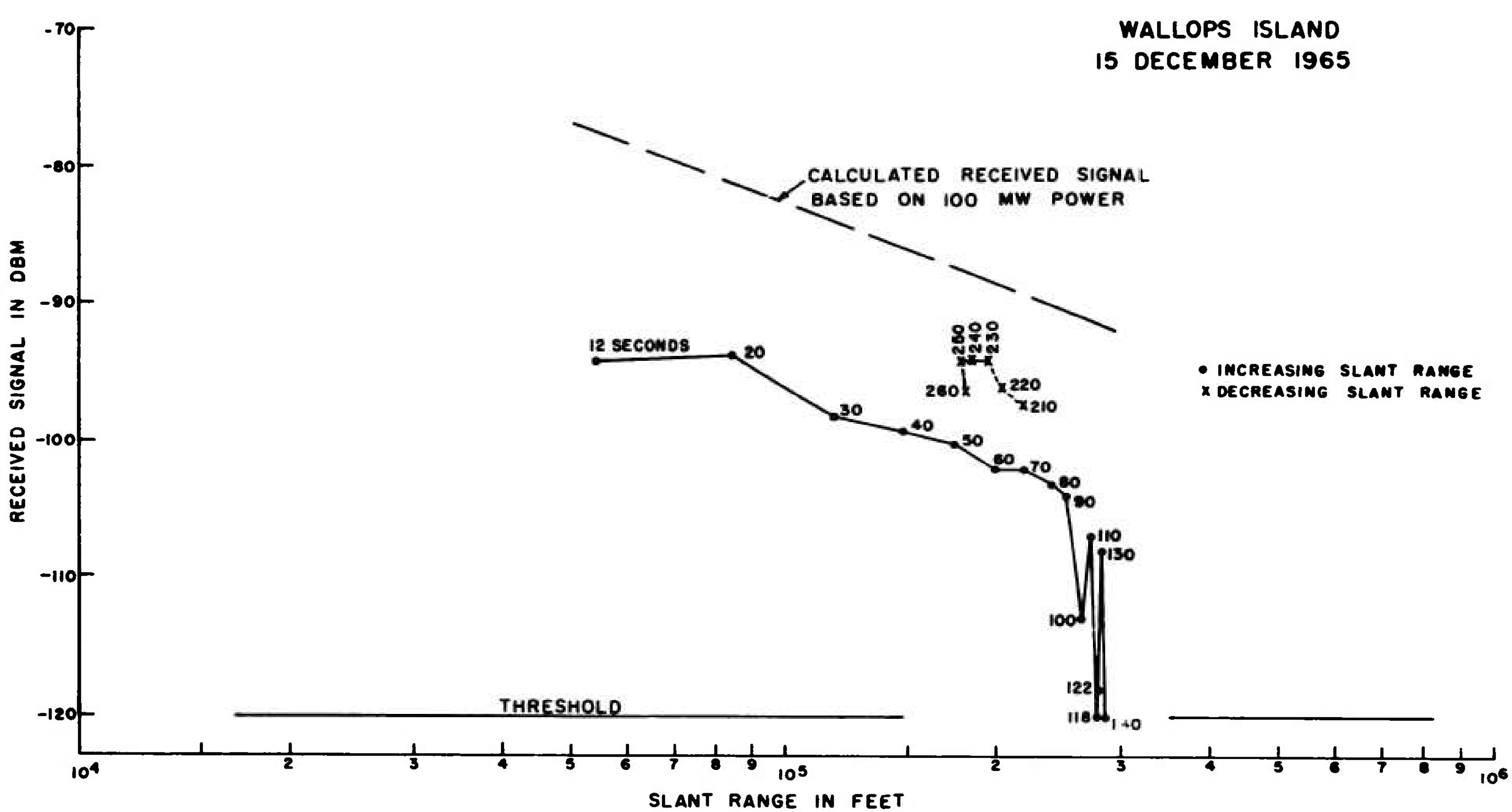


Figure 43. Received signal level vs slant range - E_1-244c

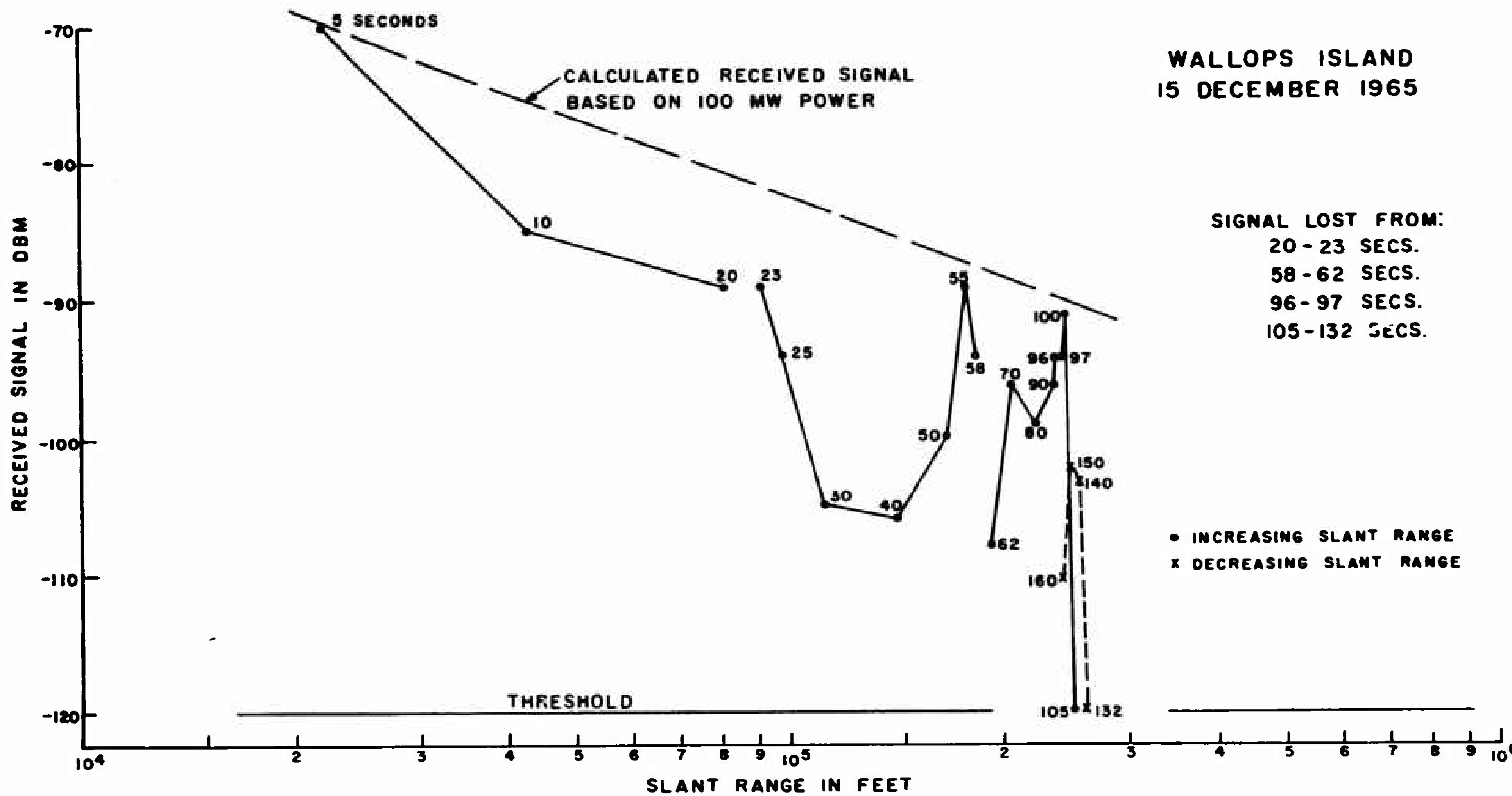


Figure 44. Received signal level vs slant range - E_1-2447

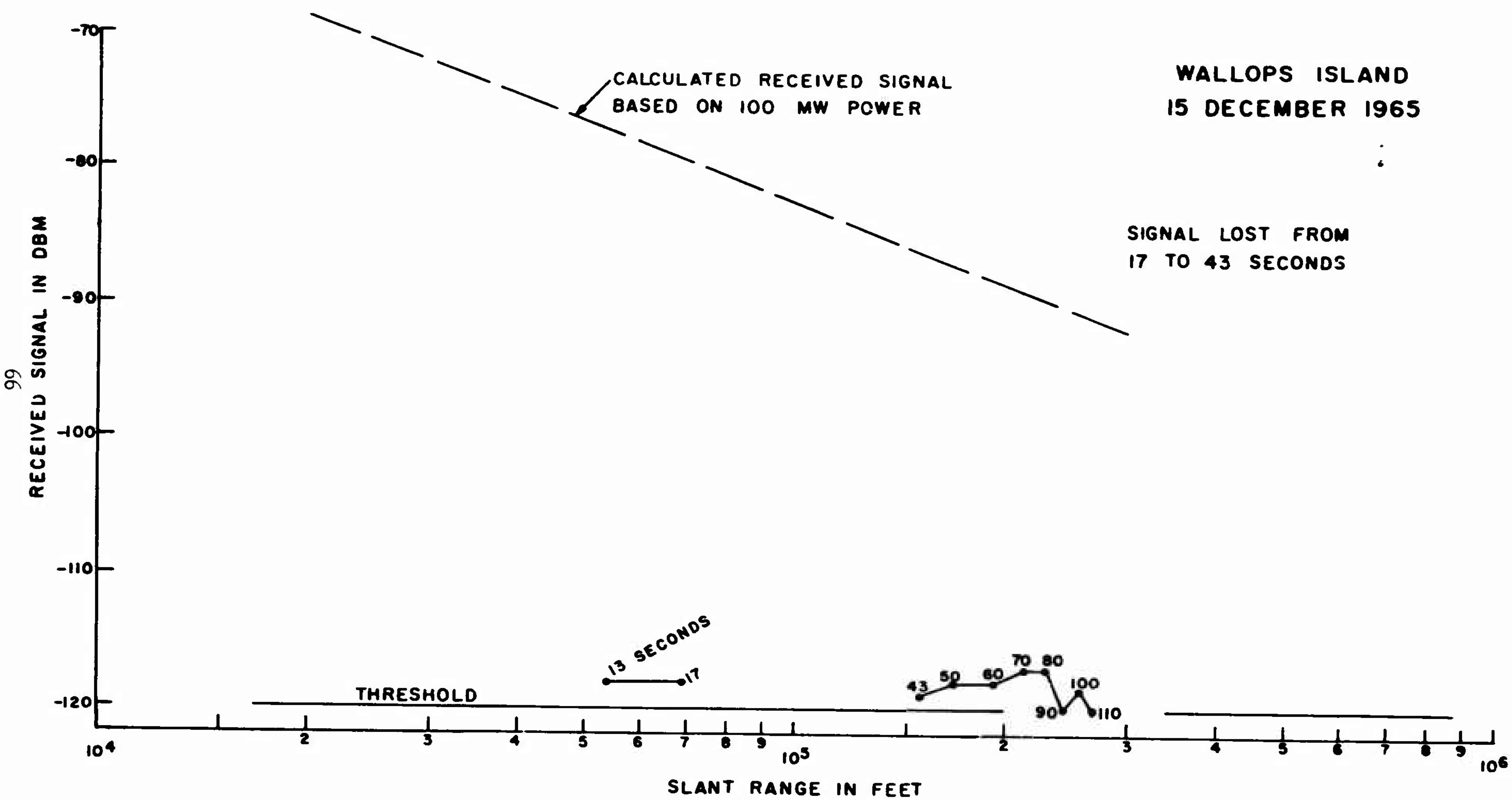


Figure 45. Received signal level vs slant range - E_1-448

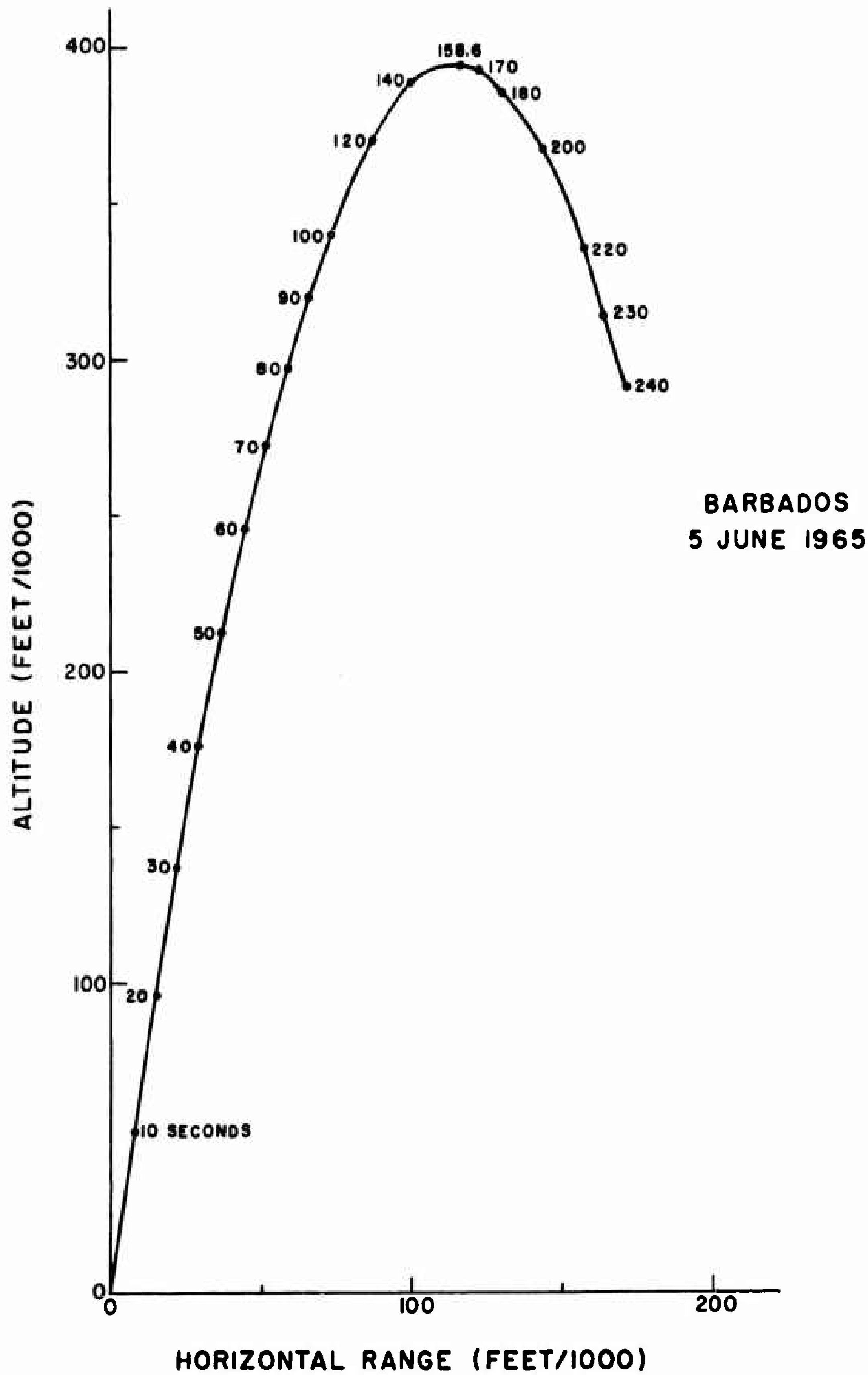


Figure 46. Radar trajectory - Brutus

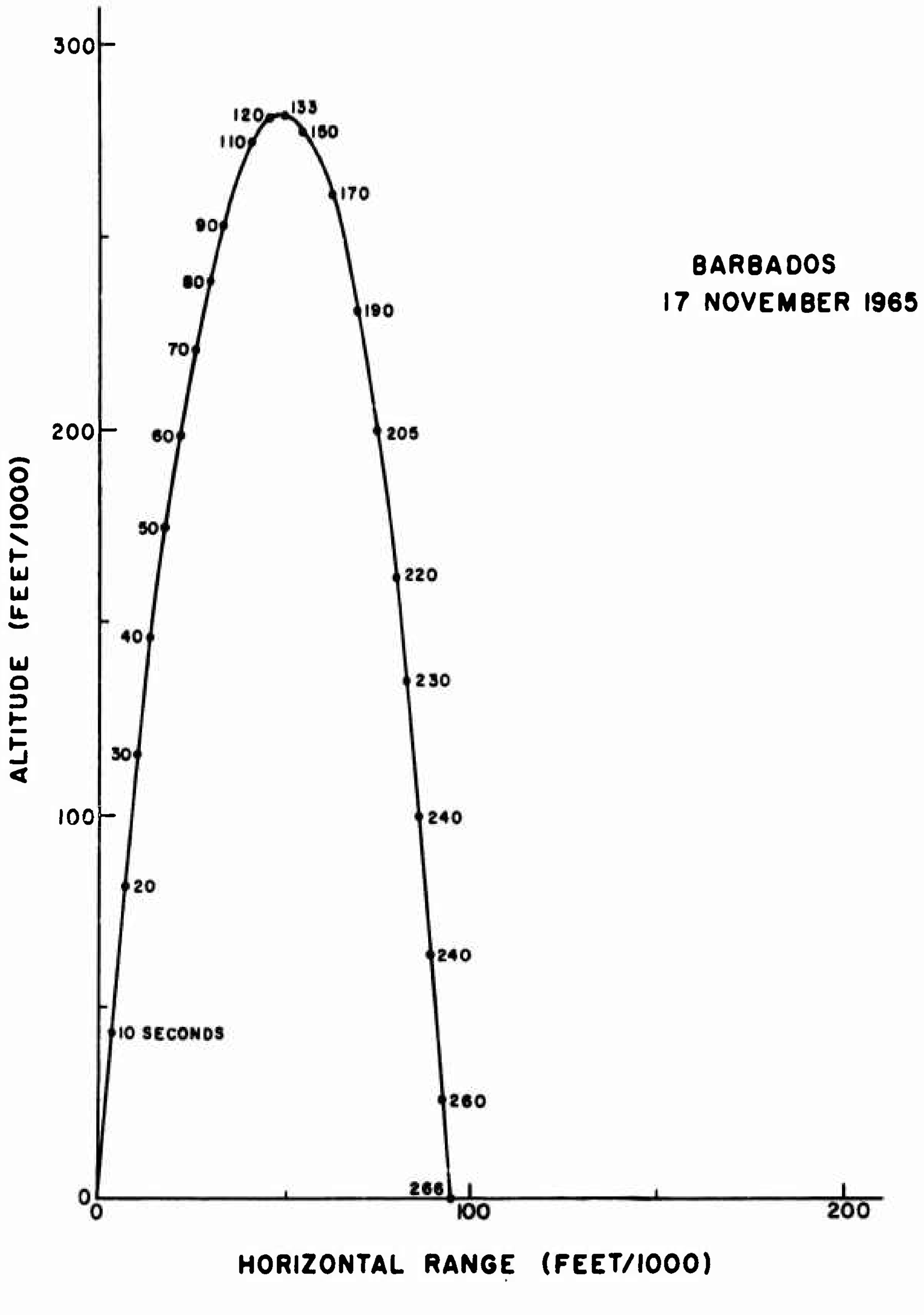


Figure 47. Radar trajectory - Bridgetown

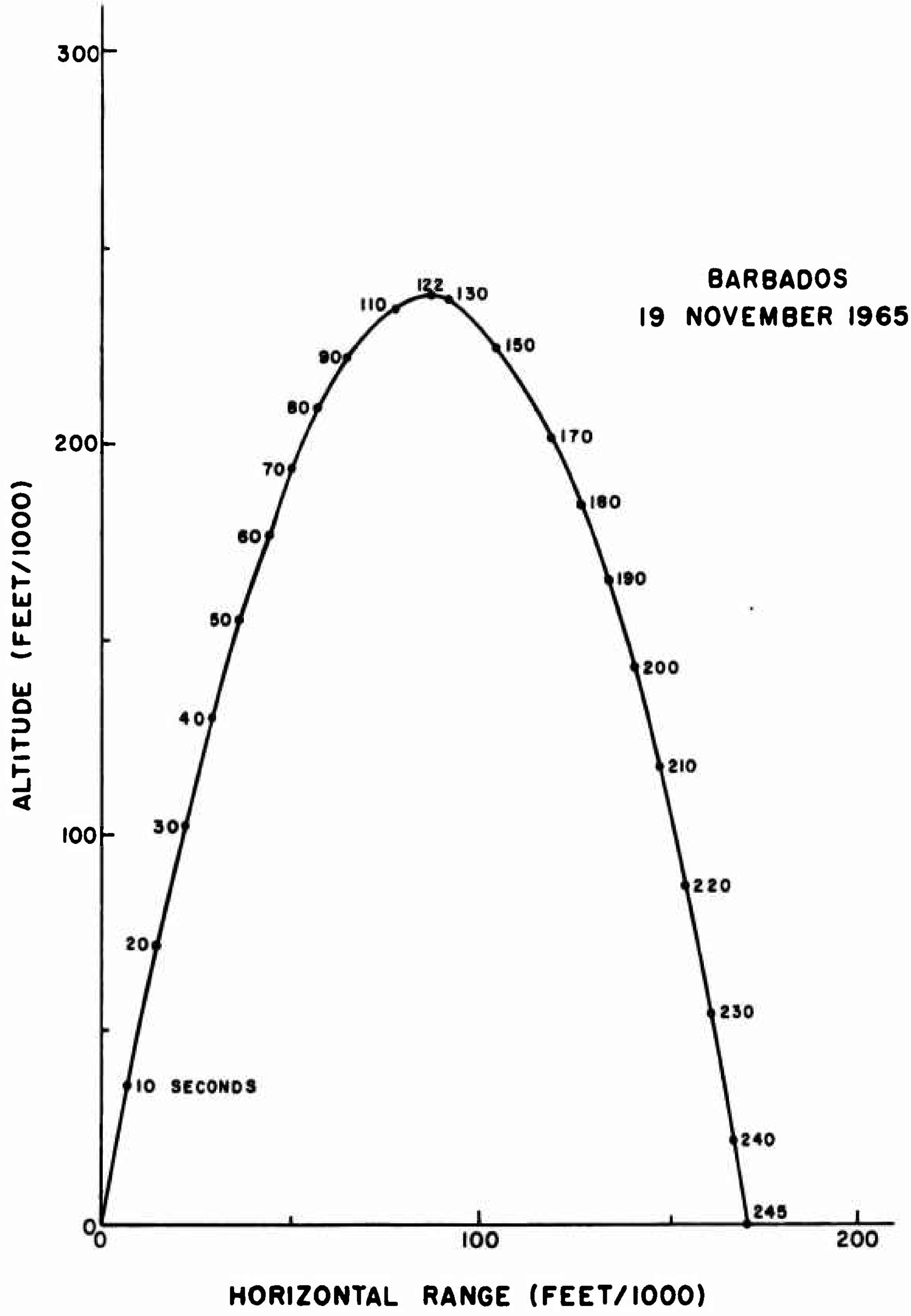


Figure 48. Radar trajectory - Kendall

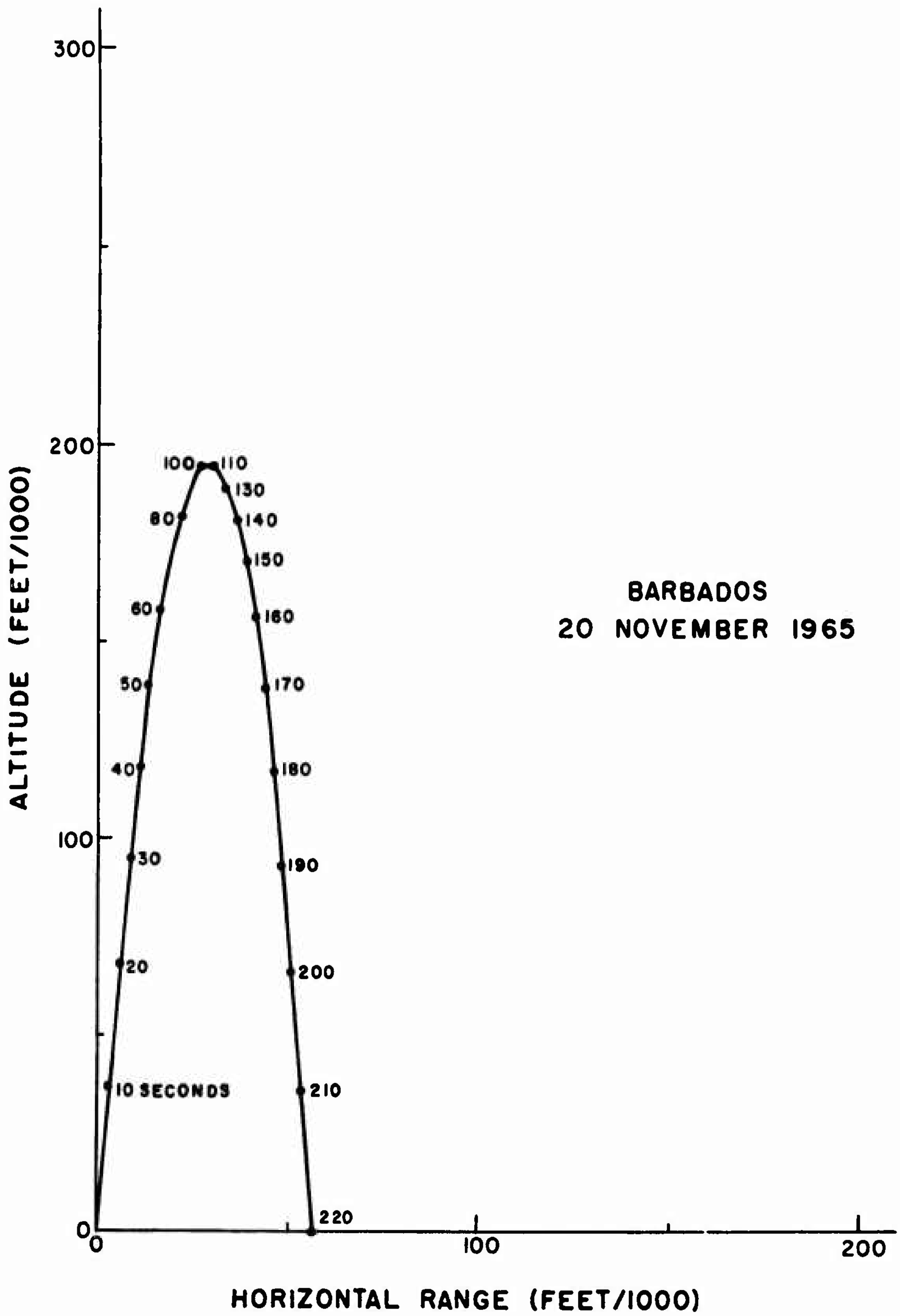


Figure 49. Radar trajectory - Lancaster

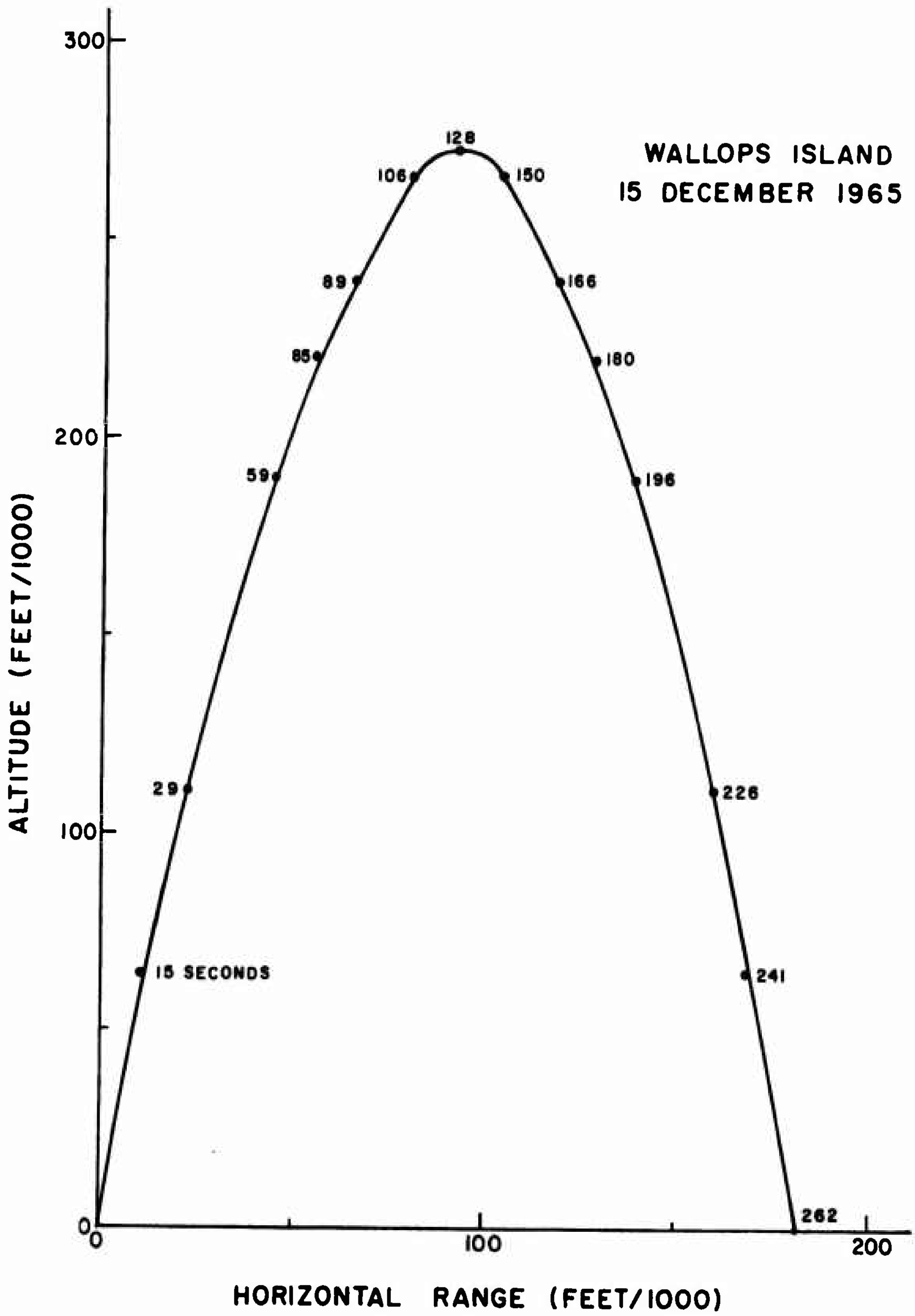


Figure 50. Radar trajectory - E_1-2446

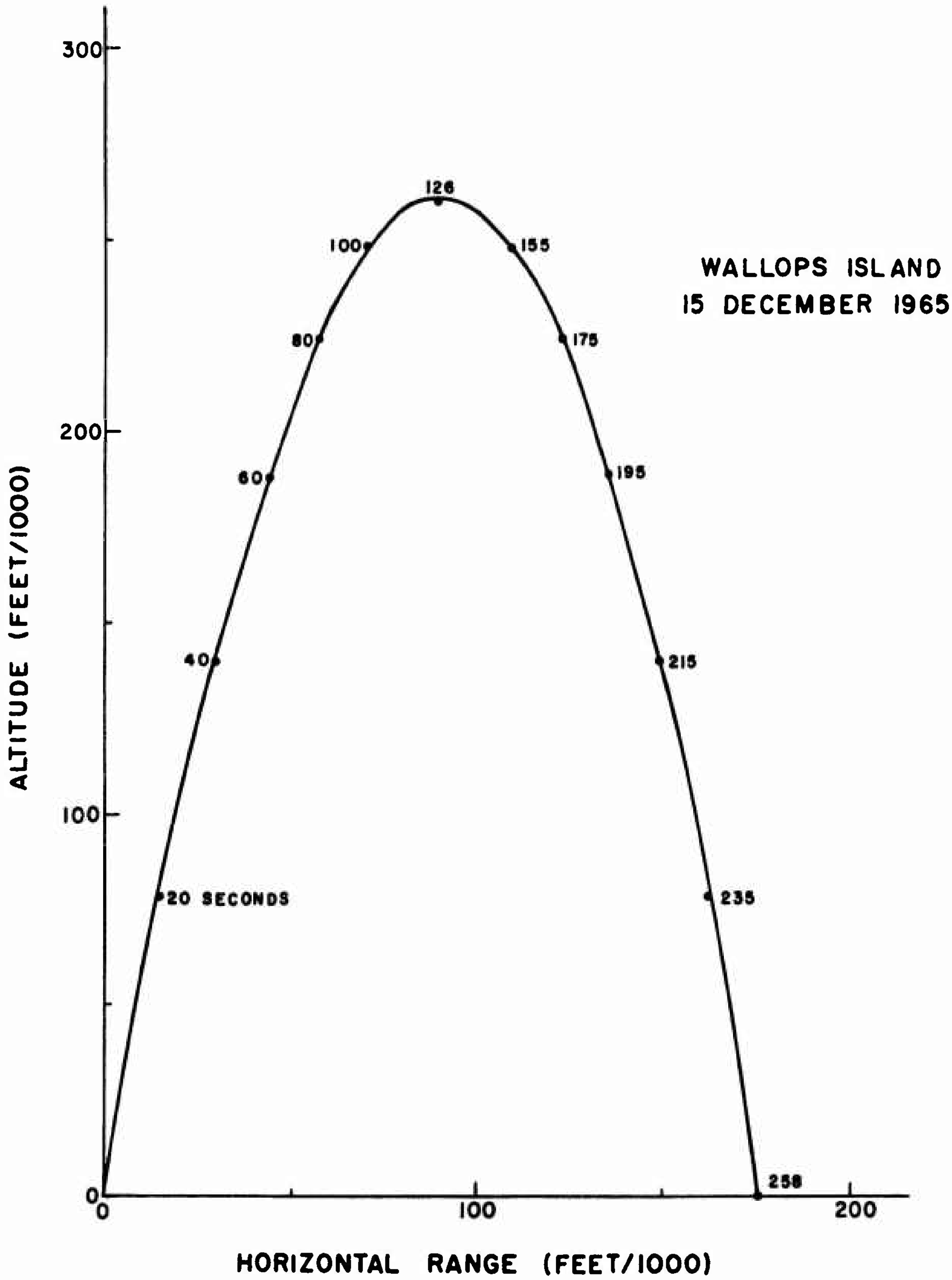


Figure 51. Radar trajectory - E_1-2447

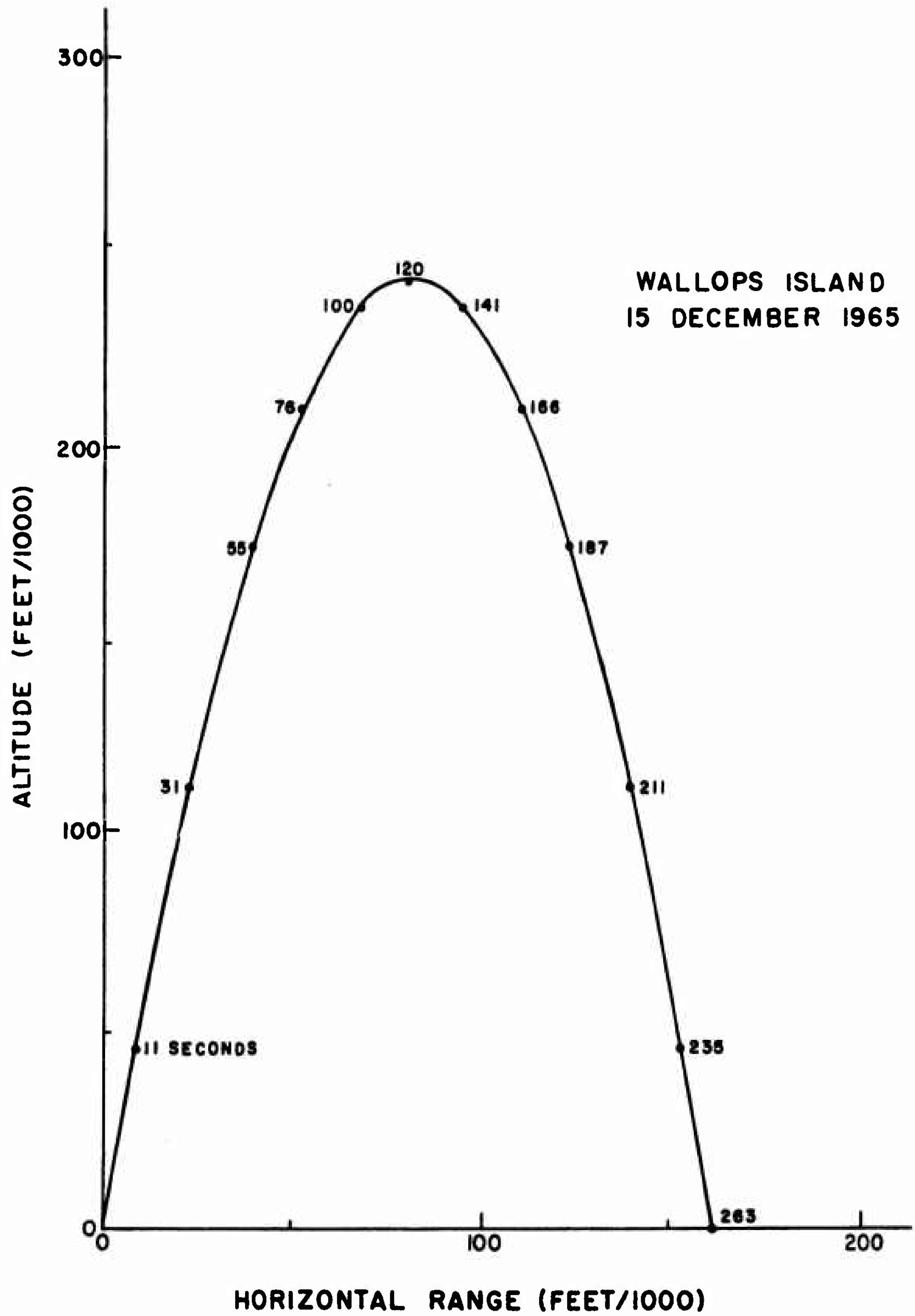


Figure 52. Radar trajectory - E_1-2448

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13. ABSTRACT

This report presents the experimental results obtained from seven Martlet II projectiles which were fired from the High Altitude Research Program (HARP) 16-inch gun at Barbados, West Indies, and three projectiles fired from the HARP 7-inch gun at Wallops Island, Virginia, during 1965. These projectiles were instrumented with the BRL 1750 MHz telemetry system and temperature, aspect magnetometer, and Langmuir probe sensors.

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Wallops-HARP						
Temperature Telemetry						

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